HOUSEHOLD CHEMISTRY;

OR,

RUDIMENTS OF THE SCIENCE

APPLIED TO

EVERY-DAY LIFE.

BY

ALBERT J. BERNAYS, F.C.S.,

LECTURER ON CHEMISTRY, AND CONDUCTOR OF THE CHEMICAL LABORATORY, DERBY.

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TO THE

REV. L. J. BERNAYS, M.A.

THIS LITTLE WORK,

CONTAINING

THE SUBSTANCE OF LECTURES DELIVERED AT ELSTREE SCHOOL,

Is Dedicated,

WITH MUCH AFFECTION, BY

HIS BROTHER.

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PREFACE.

THIS little volume is not offered to regular students of Chemistry. For such, the excellent introductions by Graham, Fownes, Brande, Liebig, Turner, and Gmelin, &c., are all-sufficient. But I have written chiefly for the young, and for those who, although people of general education, witness in the processes of daily life, some of the most important chemical operations in themselves, and all that is done for their subsistence, without either knowing or heeding those great laws by which the Author of the Universe has produced and sustains His creation. To such, it was thought, a familiar explanation of these chemical phenomena, in a familiar form, such as is usually adopted in lectures, would prove most advantageous. It might explain and clear up many things, remove many errors, and often supply

hints for doing some things better and more effectually than they are usually performed, or remedies in cases of failures or accidents, which otherwise might prove injurious or even dangerous; and, here and there, encourage men or women of sufficient talent and leisure to enter upon the serious study of science, which offers such an abundance of amusement and instruction.

I have naturally availed myself of the labours of my predecessors and cotemporaries, as every one does, and must do, when he attempts to write on any science. I have even gone so far as to make use of the very words of others, if I thought I could gain nothing in precision and clearness in employing expressions of my own. I have, however, not failed to acknowledge the sources from which I have thus drawn, except in cases where the words had engraven themselves on my memory with the facts they had taught me, and I could not remember the original mind to which I may be indebted for both. Whoever knows the works of some of our English Chemical writers, and, at the same time, those of the Germans, will understand what I mean.

The titles of the several chapters are in imitation of Professor Liebig's "Chemistry of

Food;" for, as far as I remember, I first thought of lectures under such titles after reading that beautiful work. When I first delivered the lecture on the "Chemistry of Breakfast," some four years ago, I know that the idea was suggested to me by the book just alluded to. The other lectures which make up "Household Chemistry" follow of necessity from the previous thought.

The term "Household Chemistry" was suggested to me by a clergyman residing near Derby, whose knowledge is only exceeded by his goodness, and whose friendship I have the honour to enjoy. Now, "Household Chemistry" reminds one of "Household Words;" and I cannot forego the pleasure I feel in commending it to the attention of young and old. It is indeed a most interesting work! The "Conversations on Chemistry" are beautifully written; and had I not had the first part of my book in print when they appeared, I think I should have given up the idea altogether. But these have not been continued in Mr Dickens' periodical, nor do I think that they supersede mine.

As to the arrangement, I must offer some apology. The first chapter was printed long ago, before the idea of publishing the subjects

of "Household Chemistry" occurred to me. Hence that want of methodical arrangement which I lament, but hope soon to have an opportunity to correct. The Appendix contains a number of useful and simple experiments, many of which may be understood and performed by a child of eight years old.

To those who become students of Chemistry, I would recommend the manual of Fownes for further inspection. It is compact and accurate, and contains an immense amount of well-digested information.

In conclusion, I would add one word of caution. I should be sorry in any way to encourage a mere smattering of knowledge; but the experimental parts of Chemistry are so striking, that there is danger of their fixing the attention, to the exclusion of any consideration of the relations which subsist between the phenomena. It were as profitable to witness a display of fireworks as thus to attend to chemical experiments. The penalty of the sweat of the brow is as much exacted for the enjoyment of the acquisition of knowledge as for that of the fruits of the field.

CHEMICAL LABORATORY, DERBY.

CHAPTER I.

CHEMISTRY OF THE BREAKFAST-TABLE.

In speaking of the various substances which appear upon our breakfast tables, I propose to confine myself to water and the various decoctions which are made with it; sugar, which sweetens our tea, coffee or chocolate; milk, which makes it more nourishing and palatable, with its products, butter and (incidentally) cheese; flour, from which our bread is made, and eggs, which form so agreeable and nutritious an addition to our morning meal. Meat, preserves, &c., which form such frequent accessories at our breakfasts, must be reserved for the Chemistry of another meal which will hereafter occupy our attention. We shall proceed at once to the consideration of that so-called element, on which depends so much of the comfort of our morning repast—water.

How marvellously useful and correspondingly abundant is water! The sea covers nearly three-quarters of the earth's surface; in the form of brooks and rivers it flows through the land in almost every

direction; it rises at all times as vapour into the air, forms clouds, and again descends to the earth in rain or dew.

One of the most striking properties of water is its solvent power. Very many solid substances are capable of uniting perfectly with it. Thus, when sugar is put into water, it dissolves, and we obtain a solution of sugar. Whenever solution takes place, the water possesses the taste of the substance dissolved. Thus the solution of sugar is sweet; and if the water be driven off by heat (evaporation) the solid substance may be always recovered. Owing to this solvent power, water, as it passes through the earth, takes up many solid substances which more or less injure its purity. The distinction between *soft* and *hard* water has reference to its greater or less degree of purity. River water is softer than spring water; spring water than sea water. The most abundant of all the substances extracted by water from the earth is common salt; next to it is chalk, held in solution by carbonic acid, and gypsum.

For the preparation of tea, coffee, and cocoa, the softest water is best. Rain-water may be said to be best adapted to these purposes; for as the water passes through the air, in the form of rain, it only absorbs a small portion of the air itself. If rain-water be heated, the air will be found to escape in bubbles from the water. Here again we see the importance of this solvent power; it being, by the vital air thus

dissolved in water, that fishes are able to live in that medium. Its refreshing character as a drink, moreover, is entirely owing to this property, the natural efficacy of which may be increased by forcing carbonic acid gas into it, as is done in the case of ginger beer, lemonade, sodawater, &c.

If water be exposed to heat in open vessels, it boils, or is converted into steam at a temperature of 212^0 according to the thermometer of Fahrenheit, which is that in ordinary use in this country. If the heat be continued, the whole of the water will evaporate, leaving all solid impurities at the bottom of the vessel, while the gases which the water has absorbed will evaporate with it. Pure water, unlike iron, silver, gold, copper or tin, is not an elementary substance. In whatever manner these may be treated, they do not admit of decomposition; not so however with water : by many processes we are able to separate it into two simple substances or elements. If we pass steam over iron filings heated to redness in a gun-barrel, a gas escapes which burns with flame, and the iron filings are found, if the process be continued long enough, to be converted into red oxide of iron, or iron-rust. Again, if we pass a stream of this inflammable gas over iron-rust, heated to redness, we obtain pure water. It may then be easily proved that water is not an element, but consists of two gases chemically united in the proportions of two volumes of this inflammable gas or

hydrogen, and one of another gas, known as oxygen. This hydrogen (ὑδωρ-γιγνομαι), so called on account of its capability of forming water, is colourless, tasteless and without smell; it burns readily in contact with air, and forms water. Oxygen, an element, called also vital air, as being necessary to animal existence, is the chief supporter of combustion and flame. All bodies which burn well in common air, burn with greatly increased brilliancy in oxygen gas. It will be necessary at the outset to point out a distinction of great importance to bear in mind. Most vegetable and animal substances contain a large amount of actual water, as I shall hereafter have occasion to show. But they likewise frequently contain many other compounds, in which oxygen and hydrogen are united *in the proportions* in which they are found in water. Not that these compounds contain water, but that we can compel them to form water, by destroying their organization! When therefore a compound is spoken of as containing the elements of water, I trust the meaning of the expression will be intelligible.

I have stated before, that the purer or softer the water, the better it is adapted for making decoctions. Should however water be particularly hard, a little carbonate of soda added to it will much improve it. For the preparation of a good cup of tea, coffee or cocoa, it is absolutely essential that the water boil.

And first let us speak of tea.

To give you some idea of the nature of the plant, I need but remind you that it belongs to the same natural family as the well known and beautiful plant Camellia Japonica, and that the full-grown tea-plant has a very similar appearance. The flower is not unlike that of the myrtle. China is the father-land of the *Thea Sinensis*, as the chief species is called by botanists. I do not purpose entering upon a description of the various modes of preparing the tea before it is imported into England: it will be sufficient to mention that the different kinds of tea depend upon the age of the plant, the parts which are used, the season in which the leaves are gathered, and their more or less careful preparation. Tea was first introduced into Europe by a Russian embassy at the commencement of the seventeenth century. The yearly production of tea amounts to 500,000,000 pounds.

More than one half of the weight of tea leaves consists of woody fibre; a substance insoluble in water, and without a particle of nutriment. The black teas contain more of this fibre than the green, sometimes as much as sixty-five per cent.

If to a decoction of tea, you add a solution of a salt of iron, you will find it turn black as ink. This well-marked property is owing to a peculiar principle to which the name of *tannin* has been given, because it is essential to the conversion of the skin of animals into leather. The astringent flavour of

tea is owing mainly to this substance, of which green tea contains as much as 8½ per cent. As a rule, the longer tea *stands*, or, to speak more correctly, the longer it is in contact with boiling water, the more astringent does it become. At the same time, a large amount of *extractive* is drawn out of the tea, and renders it stronger; but inasmuch as its fragrance is owing to the presence of a volatile oil, the longer the tea is allowed to draw, the less pleasant becomes the taste.

Thein, the peculiar principle of tea, is obtained by simple infusion of tea in cold water for twenty-four hours. The infusion is evaporated to dryness, and the residue, treated with alcohol, is dissolved in water, digested with magnesia, and filtered. On evaporating the liquor to a certain degree, crystals of *thein* are obtained.

To make a good decoction of tea, M. Soyer recommends heating the tea in a dry tea-pot, before the hot water is added. Be this as it may, but a small portion of boiling water should be poured on the tea, until the leaves have become fully expanded, and not until then should the remainder of the water be filled in. From three to five minutes is long enough for the tea to *draw*. All that is really good for health, will be extracted in that time. And now as to *coffee*.

Curiously enough, it belongs to the same natural family as ipecacuanha, quinine, and the plant from

which Turkey-red is obtained. The *Coffea Arabica*, the coffee plant, will, however, be admitted to be the head of the family. It is a native of the Ethiopian Highlands, but is now extensively grown in Arabia and the East and West Indies. It grows to a height of sixteen feet; the flowers are white and fragrant, but fade rapidly. The fruit somewhat resembles the cherry, and grows, like the flowers, in clusters; when ripe, it is shaken from the tree, and laid on mats exposed to the sun; and when dry, spread upon the floor, and the husks broken off by a heavy roller. The berries are then winnowed and exposed to the sun. Each plant will yield from one to two pounds. Coffee was first introduced into England in the year 1652.

Coffee contains about 70 per cent. of woody fibre. The coffee bitter is a brown transparent extract, soluble in water, and having the characteristic bitter taste of the raw coffee bean. The coffee beans also contain gum and resin, and a small quantity of a fragrant oil.

Caffein is the principle which characterizes coffee. It is analogous to *thein* in composition, and consists of carbon, hydrogen, oxygen, and nitrogen, in definite proportions. It forms white silky crystals, soluble in boiling water. It is very volatile, and is best obtained from coffee-roasters on a large scale.

According to Cadet, coffee if roasted to a pale brown colour loses 12·3 per cent., if to a chestnut-brown, 18·5 per cent.

The *flavour* of coffee, as a beverage, depends upon the *roasting* and the mode of *making* the infusion. The coffee should be mixed with a little brown sugar, and well, but rapidly, roasted in close vessels. It should be ground into fine powder immediately before it is required for use. Should the coffee beans have been roasted some time, the flavour of the infusion will be much improved by re-roasting them for a few seconds. The best coffee can only be obtained from freshly-roasted beans.

Opinions vary as to whether the coffee should be boiled or infused. If an agreeable flavour be desired, the more quickly the boiling water filters through the finely-ground and freshly-roasted coffee, the better. It is, however, necessary to use a larger quantity of coffee in this case, than when it is boiled. Boiled coffee is darker coloured, contains more bitter *extractive*, is less fragrant, and more acid than infused coffee, and is, moreover, apt to be thick. A little isinglass will, however, quickly purify it.

Cocoa.—The cocoa tree (*Theobroma cacao*) grows wild in several countries of the torrid zone of America, especially in Guiana, Mexico, and on the coast of Carraccas. The fruit is a large coriaceous (leathery) capsule, having nearly the form of a cucumber, the seeds of which furnish the buttery, slightly bitter substance called cocoa. It is now cultivated chiefly in Central America, and in British, French, and Dutch Guiana. In the West India Islands, the cul-

tivation of cocoa has given place to that of sugar and coffee.—(*Johnston's Physical Atlas.*)

Cocoa contains an oil or vegetable butter or fat, which is white, of peculiar odour, and of the consistency of tallow. It consists mainly of a hard pearly substance, ***stearine*** (from στεαρ, fat), combined chemically with an oil ***elaine***, or eleine (from ελαιον, oil). This fat disagrees with many people, but may be easily removed if the cocoa be prepared over night; the solid fat being skimmed off in the morning, before it is boiled over again. What is called homœopathic cocoa is entirely freed from fat.

Cocoa, like tea and coffee, contains a principle peculiar to itself. This principle is similar to caffeine, having the same taste, and may be prepared indifferently from cocoa or chocolate. The latter contains sugar, and frequently flour or starch, intimately admixed with the pounded nuts. It forms a wholesome and very nourishing aliment, especially valuable to travellers. In the early Spanish colonies of America, chocolate was considered, not as a luxury, but as a necessary article of sustenance. Of tea, coffee, cocoa, and chocolate, the two latter can alone be said to be nutritious. That term cannot be applied, in any degree, to coffee or tea. But what renders these beverages so curious is, that they all should contain principles so similar in composition. For, although theobromine differs from theine and caffeine in some respects, yet these principles occur

only in beverages employed for the purposes of refreshing and gently stimulating the system. Liebig has shewn all three to be closely related to *taurine,* a principle in the bile; and what renders the opinion of this sagacious chemist more probable is, that they all contribute to the formation of bile.

Sugar is the next article which must engage our attention, as it is employed to sweeten all our morning beverages.

The sugar-cane (*saccharum officinarum*) supplies us with sugar. It was cultivated in Europe before the time of the crusades. On a very small scale, sugar is still cultivated in Valencia and Granada. The plant was found growing wild in many parts of America, at the time of the discovery of that country by Columbus; and it has flourished on the coasts of China, and in the islands of the Pacific, from the remotest ages. The produce of certain districts, however, are of especial importance for the supply of Europe. These are, in the New World, the West India Islands, Guiana, and Brazils; in the Old World, Mauritius, Bourbon, Bengal, Siam, Java, the Phillippine Islands, and China (Johnston). Cane-sugar occurs likewise in the juice of the maple, of beetroots, carrots, turnips, potatoes, and in the nectaries of most flowers.

The cane, when ripe, is cut off at the root, stripped of its leaves, and passed twice through the mill, *for the purpose* of expressing the juice. To prevent

fermentation, a portion of lime is mixed with the juice, which is then quickly evaporated in boilers. As soon as it is found, on trial, to be sufficiently evaporated, it is transferred into large, flat pans or coolers; here the crystals soon separate from the *molasses* or *treacle*, which latter is nothing else but a concentrated solution of uncrystallizable sugar. The sugar itself is packed into hogsheads, and brought to this country, under the name of *muscovado* or *raw sugar*.

The process of refining consists in removing the colouring matter and other impurities from the raw sugar. A strong solution of the latter is made in water, and the serum of blood or white of egg is added. Now I need scarcely inform you, that white of egg becomes solid, when heated to a certain extent, and as the serum of blood also contains albumen like white of egg, and the one cannot be distinguished from the other, it may be employed for the same purpose. On applying heat, the albumen curdles and forms a complete network, which rises to the surface, carrying all solid impurities with it. This is skimmed off, and the sugar solution filtered through animal charcoal, which entirely removes all colour.

It is then quickly evaporated in a vacuum, or at least under greatly-diminished atmospheric pressure, by which means, exposure to a temperature sufficiently high to injure the sugar is avoided. As soon

as the sugar is capable of being drawn into threads, it is carried to the *coolers*, and agitated with wooden oars till it granulates. Upon this agitation in the cooler, the whiteness and fineness of grain in the refined sugar depend. When the sugar is in this state, it is poured into conical earthern moulds, closed at the apex of the cone, a small hole, however, being left, into which a paper plug is inserted; which has previously been soaked a night in water. When these moulds are sufficiently cold, the paper stops are removed from the points of the moulds, which are set, with the broad ends upwards, upon earthen pots to drain. As soon as the uncrystallizable syrup has been drained off by various processes, the *sugar-loaf* is baked in an oven, heated to a temperature of 95 degrees.

In making *sugar-candy*, the boiled sugar, instead of being put into coolers is poured into pots, across which threads are strained, to which the crystals attach themselves; these pots are then set in a stove, great care being taken not to disturb the liquid, as upon this depends the largeness and beauty of the candy. (Brande). *Barley-sugar* is nothing more than melted sugar.

These lumps of sugar, or the brown sugar, which we consume at our breakfast-table, what do they consist of? Chemistry offers this simple solution. Pure sugar is charcoal (carbon) combined with the elements of water. Of this you

may easily satisfy yourself. Take a lump of sugar, moisten it with hot water in a tea-cup, and pour some drops of oil of vitriol (sulphuric acid) upon it. It will immediately blacken and swell; great heat will be evolved, and the lumps of sugar be resolved into a lump of *charcoal.* You must, however, be careful not to touch it with your fingers, until it has been thoroughly washed in water, and all the acid removed from it. The cause of this change is, that the attraction of oil of vitriol for water being very great, it compels the elements of water contained in organic substances to unite, in order to satisfy this propensity.

I trust I have succeeded in conveying to you a clear idea, of all that is necessary for you to understand, of the nature of sugar and its manufacture. But there is another description of sugar, in addition to the treacle to which we have alluded, which we sometimes use to spread upon bread. You will of course understand me to speak of *honey.* I told you, that cane-sugar is found in the nectaries of flowers. This is collected by bees, and by them converted into *honey* and *wax;* that portion of the sugar not required for nutriment, the bee returns into the combs, in the form of a yellow syrup; the smell and taste of which vary according to the nature of the flowers from whence the bees have obtained the sugar. Honey contains two kinds of sugar. The solid, granular part of the honey is of

the same composition as *grape-sugar*. You may best see the latter in old raisins, which are commonly covered with its crystals. A more proper name than grape-sugar, however, is *glucose*, or *sugar of fruit*, because it is the sweetening principle of all kinds of fruit, and not of the grape alone. In composition it differs from cane-sugar only in containing a larger quantity of the elements of water in chemical combination. The liquid part of the honey contains an uncrystallizable sugar. In addition to these, honey contains a yellow colouring matter, wax, and gum.

The next object on the breakfast-table, that demands our attention, is milk. It is an object of great importance, its composition being such, that it is capable of supporting animal life, without any other food. It varies much in quality, according to the nature of the fodder on which the animal is kept. The more active the exercise taken by the cow, the smaller is the per-centage of butter, and *vice versâ*. To the naked eye, milk appears to be a uniformly white solution. But this is an optical illusion. The microscope shows us, that milk holds in suspension an infinite number of globules of different dimensions, which, by reason of their lightness, tend to rise to the surface, where they collect, and in time form a film or layer of a different character from the fluid beneath ; this film or layer *is the cream*, the subjacent liquor the *skim-milk*.

This separation appears to take place most completely in a cool temperature, from 54° to 60° Fahr. *Butter* is obtained from cream by churning. By agitation, the fatty globules cohere and separate from the watery portion, in larger or smaller lumps. The remaining fluid is the *butter-milk.* In the course of the agitation which the cream undergoes in churning, the delicate, elastic, transparent pellicles, which surround the globules, give way, and the globules of oil, fat, or butter, being no longer prevented by the skin, are left free to cohere. The time required for the process is dependent upon various circumstances. In summer a cool, in winter a warm place is chosen for the operation. On being taken out of the churn, the butter is kneaded and pressed, and washed under water to free it as much as possible from the butter-milk and curd which it always contains; and to the presence of which is to be ascribed the speedy alteration which butter undergoes in warm weather.

The fatty matter which constitutes the *chief* part of the butter, consists of materials similar to the fat or butter of cocoa. Margarine gives solidity to the butter. In summer the elaine predominates, and the butter consequently is less firm. In winter the margarine predominates, which, in conjunction with the lower temperature, makes it comparatively hard. *Butyrine* is an oily substance, amounting to about three *per cent.*, and gives the tasty principle

to the butter. This is very liable to become sour and to be converted into *butyric acid*, which makes butter to become rancid. It may, however, be removed by repeated washing with hot water.

Butter is usually salted, in order that it may be kept longer. It may be preserved quite fresh for a long time, by covering it with syrup, without the addition of any salt. The syrup may be washed off it when the butter is required for use. The water of milk holds in chemical solution a considerable per-centage of curd, or *caseine*. Fresh milk contains nearly one-half per cent. of soda in solution, which has the property of dissolving the curd. It serves for the formation of the blood, and for the nutrition of the animal tissues. *Cheese* is a mixture of caseine with a greater or less quantity of butter.

When fresh milk is allowed to stand for some time, the lighter suspended particles rise, and form, as is well known, *cream*. When kept for five or six days, at a low temperature, it evolves nearly the whole of its cream, and underneath is found a liquid resembling milk and water. According to Berzelius, cream consists of

Butter	4.5
Caseine	3.5
Whey	92.0
	100.0

Milk, when left to itself, as is well known, becomes

sour and curdles. This is owing to the fact, that the *sugar of milk*, (*lactine*), which gives sweetness to it, becomes converted into an acid. This *lactic acid* combines with the soda, which holds the caseine in solution ; and, as the latter is insoluble in water, the milk is converted into curds and whey. After the cream has been removed, there still remains a large per centage of cheese, as the following analysis of skimmed milk will shew :—

Water	92·87
Curd, with little butter ...	2·80
Sugar of milk	3·50
Ash	0·83
	100·00

Skimmed milk will therefore likewise curdle on exposure to air. The whey still contains sugar of milk, a substance similar to white of egg, and various salts. The composition of fresh cow milk, according to Henry and Chevallier, is as follows :—

Caseine	4·48
Butter	3·13
Sugar of milk	4·77
Soda and salts	0·60
Water	87·02
	100·00

These few remarks will have enabled you, in some degree, to appreciate the value of milk as an article of food.

Having devoted so much of our attention to liquids, let us now turn to the consideration of the more substantial articles of consumption at the breakfast-table ; and bread, as the most important, must occupy us first. The valuable grain which we call wheat, is the produce of several kinds of the genus *triticum*, winter wheat and spring wheat (*triticum hybernum* and *triticum æstivum*), being the most common. Wheat, like rye, oats, barley, and rice, belongs to a natural family,—*graminaceæ* (grasses)—plants which number among them some of the most useful and the longest cultivated in Europe. Many indications, botanical as well as historical, warrant the presumption, that Tartary and Persia are the native countries of wheat, rye, and oats ; this, however, is very uncertain.

In wheat, rye, etc., *starch* constitutes the principal part of the grain. Indeed, next to wood, starch is the most abundant product of the vegetable kingdom, and from it the wood itself is formed. To obtain starch from wheat, the grain is either coarsely ground, and mixed with water in large tubs ; or, is put to steep in sacks, until it becomes so soft that a process of kneading suffices to set the starch at liberty. It must not, however, be supposed that *ordinary* starch is prepared from wheaten flour, though it may be made from it in the manner described. On a small scale, starch may be obtained from wheat, by mixing up dough with water, and

washing it on a linen cloth with water. A milky liquid passes through, which, when set aside, deposits white powder. Sago, tapioca, cassava, and arrow-root, are nothing more nor less than starch, and form a light wholesome food. Pure starch is a white substance, half-again as heavy as water, and insoluble even in boiling water, in which it becomes thick and gelatinous, having the *appearance* of solution, owing to the bursting of the little sacks in which each granule is enveloped. In composition, starch is very easily converted into grape sugar. This you will perceive more readily, when you compare the composition of both :—

	C.	H.	O.*
Grape sugar	12	28	28
Starch	12	21	21

Thus, by combining with seven atoms of the elements of water, this change is effected. An infusion of malt in a solution of starch, kept for some time at 150°, will produce this change, as we see in the process of brewing.

Starch, from its ready convertibility into sugar, is well adapted for carrying on those changes which occur in the juices of vegetables ; and stored up, as it is, in the seeds, roots, and pith of plants, supplies

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* The elements are generally expressed by chemists by the initial letters of the Latin names. Thus, in the present instance, C. stands for Carbon, H. for Hydrogen, O. for Oxygen.

by its decomposition the materials for many of the most essential vegetable products. It furnishes, likewise, an important article of the food of animals. It does not serve to increase the bulk, but supplies the material for keeping up respiration and the animal heat of the body. The fat of man and animals is, in all probability, derived from starch. The average per centage of starch is as follows :—

Wheat flour	39 to 77
Rye flour	50 to 61
Oatmeal	70 to 80
Rice flour	84 to 85

The most important nutritive element of wheaten bread is the *gluten* which it contains. This is obtained with great facility, by simply kneading a mass of dough under a small stream of water, by which the starch, as before described, is carried off, leaving in the hand a greyish highly-elastic substance—the *gluten* of chemists. It is very rich in nitrogen, but contains likewise carbon, hydrogen, and oxygen. The adhesiveness of gluten, is owing to the presence of a very sticky substance, called *gliadine*.

The washings, collected and allowed to stand, soon become clear ; the starch which was suspended in the liquid subsides, accompanied by flakes of an animalized matter. If the clear liquor be decanted and boiled, a white froth appears upon its surface, which, when skimmed off, has the appearance of coagulated *white of egg*, and possesses the same pro-

perties, as well as the same composition. The water from which the albumen is separated, contains all the still *soluble* portions of the flour. On evaporation, we find substances resembling *gum* and *sugar*, together with *saline matters*. These latter aid in the formation of bones. The following indicates the per centage of elements in the *fibrine*, *gluten*, *albumen*, and *caseine* of wheaten flour :—

Carbon	53·5
Hydrogen	7·1
Nitrogen	16·0
Oxygen, Sulphur, and Phosphorus	23·4
	100·0

Including all the nitrogenized substances of the grain of wheat under the head of *gluten*, we find it varies from eighteen to even as much as thirty-five per cent. Twenty per cent. may be considered a fair average.

In making bread in the ordinary way from wheaten flour, the yeast added to the dough changes the sugar, which, as we have seen, the flour naturally contains, into *alcohol* (spirits of wine) and carbonic acid gas. The latter forces the tough dough into bubbles, which are still further expanded by the heat of the oven, which at the same time dissipates the alcohol.

Leaven is merely dough, in a state of incipient putrefaction. When, therefore, it is mixed with a

quantity of fresh dough, the same process of change takes place as when yeast is employed. It is, however, but little used at present, as it frequently communicates a disagreeable odour and a sour taste to the bread.

In making bread the starch is, *in part*, subject to a very extraordinary change. By the heat in the oven it becomes converted into *dextrine*, also called British gum, which is easily soluble in water, and therefore more digestible. That this formation really does take place, may be easily proved by wetting with a moist sponge the exterior of a loaf of bread, and returning it to the oven. After a few minutes, the crust will be found quite shining, as if covered with gum. The water has brought out a portion of the dextrine.

In making *toast*, nearly the whole of the starch becomes thus changed, and a small portion of it, as well as of the gluten, is carbonized. There are two great objections to the use of white bread. Firstly, and as a rule, the preference given to very white bread, leads the baker to the liberal use of alum. The proportion of alum used in a quartern loaf, is said to vary from twenty-two grains to three times that amount. The baker is enabled to use an inferior flour, which thus assumes a very white appearance; and, owing to the property of alum absorbing and retaining water, a smaller amount of flour is necessary to make up the full weight of the loaf. The

natural tendency of the white bread to produce constipation of the bowels, is greatly increased by the use of alum. Secondly, the removal of the bran renders the bread less nutritious. The bran is especially rich in phosphate of lime, or bone-earth, in fat, and in nitrogen. A man might live upon *brown* bread and water; he would languish and die upon white bread and water. For young children, indeed for all persons still growing, brown bread is incomparably superior to white. The prevalence of bad teeth among the English, may be in part owing to this universal preference given to white bread.

Owing to the fact that in the ordinary process of bread-making, considerable waste is occasioned (by the vinous fermentation), several methods have been suggested to prevent this. The one reçommended by "a Physician," is based upon the fact, that when carbonate of soda is mixed in the proper proportion with spirits of salt (hydrochloric acid), the common culinary salt is formed; the carbonic acid being set free, expands the dough so as to form bread. It is very necessary that the soda should be equally diffused through the flour, for if it be deficient in any part it will not rise there; and if in another part there be too much, or little lumps of it, in that place the bread will shew a yellowish spot. The best mode of mixing it, is to shake the soda from a small sieve over the meal or flour with one hand, and stir them together with the other, and then to pass the

mixture once again through the sieve. The acid should then be poured into the water, stirred and mixed intimately with the meal or flour, and the water so prepared as speedily as possible, a wooden spoon being used for the purpose. The bread should be put into a quick oven without loss of time.

The prescription given by "a Physician," is as follows :—

To MAKE WHITE OR FLOUR BREAD.—Take of flour three pounds avoirdupois ; bicarbonate of soda nine drachms ; hydrochloric acid (specific gravity 1·16) eleven and three-quarter fluid drachms ; water, about twenty-five fluid ounces.

To MAKE BROWN OR MEAL BREAD.—Take of wheat meal three pounds ; bi-carbonate of soda, ten drachms ; hydrochloric acid (specific gravity 1·16), thirteen fluid drachms ; water, about twenty-eight fluid ounces.

Another method of obtaining unfermented bread, is to mix sesqui-carbonate of ammonia with the flour. About two drachms to the pound will, I think, suffice. The heat of the oven first volatilizes a portion of the carbonic acid of the carbonate, and then the rest of carbonate of ammonia as such.

Bread made in the ordinary way is sometimes sour. This is owing to the formation of acetic acid (vinegar), and lactic acid (acid of milk).

Before concluding this part of my subject, I would mention that it is of great importance that the bread

be baked in an oven sufficiently hot to harden the sides of the cells (which are artificially formed by the escape of the carbonic acid), so as to retain their form after the loaves are removed. When bread is very rich in gluten, it requires greater heat than usual, in order to get rid of the excess of water. The more evenly porous the bread appears after baking, the more wholesome is it, and vice versâ. Three pounds of flour usually retain after baking one pound of water. If alum be added, it will hold half a pound more.

Having called your attention to the nature of some of the most important elements of the breakfast-table, we will proceed to another. From what we have already said, we are now in a position easily to explain the nature of an *egg*, and the change it undergoes in boiling. An egg-shell is of the same composition as common chalk. If spirits of salt (hydrochloric acid) be poured upon egg-shells, the whole, with the exception of a small amount of membrane, is dissolved, with effervescence arising from the escape of carbonic acid gas. On close inspection of the shell, it will be found to be perforated in every part. These perforations or pores, serve for the admission of air to the young bird during the process of hatching. The admission of air through them, is the reason why the egg in time becomes rotten. The best mode of preserving eggs fresh, is to paint them with lime, milk, or oil, and then to lay them in sawdust.

On breaking an egg we first meet with a colourless liquid, contained in cells; this is the *albumen* or *white of egg*. If it be dried at a temperature of 120°, it has the appearance of gum, and will be found to have lost seven-eighths of its whole weight. But if the heat be increased to 160°, the albumen coagulates, and is no longer soluble in water. Hence is white of egg described in two states.

1. *Dry soluble albumen*, when placed in water, first swells up, and then dissolves, forming a liquid of an opal tint. This liquid has the property of being coagulated by corrosive sublimate, with which it combines, forming an insoluble compound; and is in consequence the best known antidote to that most fearful poison. Four grains of corrosive sublimate are said to be rendered harmless by the contents of a single egg.

2. *Coagulated albumen*, yields from one to two per cent of phosphate of lime (bone-earth). Soluble albumen appears to possess the property of dissolving bone-earth, a property which enables the blood to convey to the bones their earthy parts (Liebig). Albumen contains both sulphur and phosphorus. The former is the cause of the blackening of a silver spoon, when left in an egg for a short time, owing to the formation of sulphuret of silver.

When analysed, albumen is found to consist of carbon, hydrogen, oxygen, and nitrogen, with less *than one per* cent. of sulphur and phosphorus toge-

ther. It has the same composition as vegetable albumen.

The *yolk* of the hen's egg consists of white of egg, in which about thirty per cent. of a yellow oil is swimming. It coagulates when heated, owing to the albumen which it contains. This oil may be removed by strong pressure. In composition it resembles most oils, and consists of carbon, hydrogen, and oxygen in definite proportions, together with sulphur and phosphorus. It is of a bright yellow colour, and has a sickly smell. The only tasty principle of the egg, is the oil in the yolk. When an ordinary-sized egg is boiled in water, it loses about three-tenths of a grain. Of an egg which weighs 1000 grains,

The *shell* constitutes	... ...	106·9	parts
The *white*	„	604·2	„
The yellow	„	288·9	„
		1000·0	

In a hard-boiled egg, the albumen of the white and the yolk become insoluble in water and less digestible.

Undoubtedly, the true starting-point of all the animal tissues is albumen. This appears from the phenomena of incubation, where all the tissues are derived from the albumen of the white and of the yolk, with the acid only of the air, of the oily matter of the yolk, and of a certain proportion of iron also found in the yolk. It appears, therefore, clear from

this, that albumen is capable of passing into fibrine, caseine, membranes, horn, hair, feathers, etc. (Liebig).

An attentive consideration of the various substances partaken of as food at breakfast, will suggest a division of them into two classes. We have seen that our food in some cases contains nitrogen, in others not. Butter, sugar, sugar of milk, honey, starch, oil of eggs, are rich in carbon, and serve not only to maintain the animal heat of the body, but for the support of respiration and the formation of fat. The caseine of milk, the albumen, gluten, and fibrine of bread, the albumen of eggs, are substances rich in nitrogen, and serve to increase the mass of the human frame.

CHAPTER II.

CHEMISTRY OF THE ATMOSPHERE.

The most intimate relations exist between the constituents of atmospheric air, and those of plants and animals; so intimate, indeed, that an intelligent knowledge of the varied properties of the air, will enable us to understand a host of the phenomena which cross our daily path. By far the greater bulk of substances constituting the vegetable kingdom, such as water, starch, sugar, wood, gum, the various oils so remarkable for their odours, and the resins, are contained, in an elementary form, in the atmosphere. In the animal kingdom also, with the exception of the bones, and the small portions of earthy matters pervading every liquid and solid part of the frame, we find nothing which is not discoverable in another form in the atmosphere. The very life of plants and animals depends upon air, and the wholesomeness of the latter, upon the relations existing between the animal and vegetable kingdoms.

The air is of itself colorless, but in the mass has probably a blue colour. It is supposed to absorb the red and yellow, and to reflect the blue rays of the sun; so that its colour is owing to reflected light. At great heights the sky appears of a deeper blue, being mixed with black, owing to the absence of white reflecting clouds.

The atmosphere is limited in extent; but whether from cold, or from a limit to the expansibility of its particles, is not well ascertained. It is, however, supposed to extend to a height of nearly forty-five miles, in a state of perceptible density. It is as much a material substance as iron or water, The weight of one hundred cubic inches of air, at the ordinary temperature, has been computed at thirty grains and a half. It may therefore be easily imagined with what force the atmosphere presses upon all bodies. In accordance with the general law of fluids exerting pressure equally in all directions, the weight of the air is not usually felt. But were it not for this law, the weight of the air would be sufficient to crush us. As a familiar illustration of the weight of the air, may be instanced a walk in a clay-field on a wet day. The difficulty of lifting the foot, is entirely owing to the pressure of the air from above. This pressure is, in round numbers, equal to fifteen pounds upon each square inch of surface.

Atmospheric pressure is exerted upon everything

on the earth's surface. If a glass tube, closed at one end, be partly filled with water, and inverted in a basin also filled with water, the fluid will not fall in the tube, but remain suspended at a much higher level than that of the water in the basin. This is owing to the pressure of the air upon the water in the basin; for, if the tube were perforated at the top, the pressure of the air would be exerted equally on the water in the tube and in the basin, and accordingly the water would fall to the same level. If the tube be of any length under thirty-three feet, filled with water and inverted, the pressure of the air upon the water in the basin will be sufficient to keep the tube full.

If the air be exhausted from the tube by means of the air-pump, and the open end then placed under water, the water will be found to rush with violence up the tube, and so fill it. At the height of thirty-three feet, the column of water becomes balanced by the pressure of the atmosphere; any change in the pressure of which must, of course, be attended by a change in the height of the column of water. Such an instrument becomes therefore a *measurer of atmospheric pressure*—a *barometer*. Water barometers (an example of which may be seen in the Hall of the Royal Society's rooms) are inconvenient, in consequence of their length. If we can therefore find a heavy liquid, to replace the water, the tube need not be so *long*. Now quicksilver, or mercury,

happens to be thirteen and a half times heavier than water; the tube therefore requires to be but 1-13½ the length. A column of mercury, thirty inches in height, exactly counterbalances the average pressure of a column of air of equal diameter. The vacant space above the quicksilver, in the closed end of the barometer-tube, is called the Torricellian vacuum, from its having been observed by Torricelli to be free from air.

There are several modifications of the barometer; their action, however, is much the same as that which I have just described.

Though not strictly connected with the subject, I may here say a few words about the barometer as a weather-glass. East and north winds usually cause the glass to rise; south and west to fall. The first named are cooler, as they come from cold regions; and drier, because they pass over continents: while the latter come from warm regions into colder, and thus they lose some of their capacity for water, but as they pass over vast seas, they again attract much moisture. It therefore rains less frequently with north and east winds than with south and west. Wet and stormy weather is preceded by a fall of the mercury; fair and calm, by a rise.

As might be expected, the air is both tasteless and inodorous: were it otherwise, our sense of taste and smell would be useless.

It consists of a mixture of several gases. Ac-

cording to the latest experiments, one hundred volumes of air are found to contain twenty-one volumes of *vital air* or *oxygen*. The latter is most abundantly diffused throughout nature, forming as much as eight-ninths of the weight of water, one-fifth of the weight of air, and nearly one-half of the weight of the solid rocks which constitute our globe. It is also largely contained in all animal and vegetable substances. Of the importance of oxygen too high an idea can scarcely be conceived. Neither respiration nor combustion can be carried on without it; no human being or animal can live, nor candle nor fire burn in the absence of it. Water also, absorbs it; hence it is always found in rain, snow, spring and river-water. The oxygen contained in rain, as it trickles through the soil, ministers to the growth and nourishment of plants in various ways. It exerts a very powerful influence upon some of the constituents of the soil, rendering them soluble in water, and is the cause of the decay and putrefaction of vegetables. It has neither colour, taste, nor smell; its specific gravity is greater than that of air, being as 1·111 to 1·000.

Mixed with the vital air, the atmosphere is found to contain in one hundred volumes, seventy-nine volumes of another gas, called *azote* or *nitrogen*. The name azote (from *α*, privative, and ζωὴ, life), was given to it on account of its unfitness to support life; and it was called nitrogen, as being a

constituent part of nitric acid. Like oxygen, it has neither colour, taste, nor smell; but it does not support respiration or combustion. It is rather lighter than atmospheric air, compared with which its specific gravity is as 0·972 to 1·000. It has no action upon vegetable colours. It is a constituent of many vegetable and of most animal substances; indeed, as we have seen in the former chapter, no kind of food can be considered nutritive, or, at least, capable of forming flesh and blood, unless nitrogen forms a portion of it. Although it will not support respiration, the fact of its forming so large a portion of the air, proves its harmlessness. We are doubtless unacquainted with many of its uses, but we know that its presence in the atmosphere is essential to temper the effects of oxygen upon the system. Pure oxygen, if inhaled by any human being or animal for any length of time, will cause inflammation, and, ultimately, death. Nitrogen manifests so few and such feeble attractions or affinities towards oxygen and other bodies, that it is eminently adapted for admixture with other gases.

Another important constituent of the atmosphere, although, however, very small in amount, is *carbonic acid*, which is also called fixed air, or choke-damp. According to the most recent experiments, one hundred volumes of inland air, contain, on an average, 0·05 volumes of carbonic acid gas. The air *on mountains* contains more carbonic acid than that

of low lands, probably because in the higher regions the air meets with fewer plants, and the carbonic acid is less likely to be absorbed by moisture. The maximum quantity of carbonic acid in the atmosphere, is found towards morning; the minimum, at the close of day. Its sources are very numerous. At every respiration of men and animals, a portion of the carbon of the blood unites with the oxygen of the air, and forms carbonic acid. The combustion of wood and coal, the processes of decay, fermentation, and putrefaction, are largely productive of this gas. Whenever carbon unites with oxygen at high temperatures, carbonic acid is always the result. For the purpose of forming an idea of the quantity of carbonic acid given off to the air in a single place, it may be mentioned that in London and its suburbs two million tons of coal are annually consumed, the combustion of which requires upwards of four million tons of oxygen, which must be provided by the atmosphere. To this carbonic acid, resulting from the union of the coal with oxygen, must be added that produced by the burning of so many gas-lights, candles, &c. Again, there are congregated in the metropolis upwards of two million of human beings, each of whom will, on an average, daily supply four pounds of carbonic acid to the atmosphere; and, if to this be added the production of this gas from horses and other animals, and from the processes of fermentation in breweries and dis-

tilleries, it will appear that London alone supplies the enormous quantity of eleven million of tons annually to the atmosphere.

Carbonic acid, then, is of very frequent occurrence. Water, at ordinary temperatures, absorbs its own volume of it. Hence we find it, more or less, in all waters. At ordinary temperatures it is a colourless gas, of a slightly irritating odour, and, when inhaled pure, or even with a considerable quantity of air, it causes death. Its specific gravity is far greater than that of air, being as 1·525 to 1·000. It is therefore liable to accumulate in holes and caves of the earth, and even in rooms not properly ventilated. In close rooms the oxygen of the air is, by the process of respiration, converted into carbonic acid; and the atmosphere would soon become unfit for breathing, were it not for the change of air which takes place through the crevices of doors and windows. Since, then, carbonic acid is of such frequent occurrence, being always present in the air, and being constantly formed at the expense of the oxygen of the latter,—how is it, it may be asked, that the quantity of oxygen does not unduly diminish, and the carbonic acid increase to a most injurious extent?

This question, the solution of which is most important, is intimately connected with another,—namely, whence do plants obtain their carbon? The most simple experiment will prove the pre-

sence of the carbon in the vegetable kingdom. If we char a piece of wood, a stalk, a leaf, or a piece of dry potatoe, the *hydrogen* contained in these, having a greater affinity or attraction for oxygen than the carbon has, the latter becomes manifest, and appears as a black substance like charcoal. This substance is impure carbon. It may, I think, be assumed that carbon being an elementary substance, plants cannot possess the power of producing it themselves, but that they must derive it from surrounding substances. Now the chemical phenomena of vegetation are accomplished by the concurrence of the elements of the air, of water, and of the soil. A seed, with reference to its organization, consists of an *embryo* (which includes the germs of the root and of the stem), and of the *cotyledon* or *cotyledons*, which form the bulk of the seed. All seeds contain starch and gum, a substance (as in peas and beans) resembling cheese, oily matters, and a certain small portion of ashes; which latter may be seen, if the seed be burnt.

If some seeds be moistened, and placed under a glass containing common air, all the signs of germination will soon be perceived. On examination of the air, after a few days, it will be found to be altered in its composition. It will be seen that a portion of its oxygen has disappeared, and a corresponding volume of carbonic acid has been produced. Now *we know that* seeds will not germinate in an

atmosphere deprived of oxygen, and that the process of germination is always accompanied by the formation of carbonic acid. Germination and respiration are therefore akin in this property. Some seeds are known to germinate under water; this is owing to the constant presence in the water of atmospheric air in a state of solution. Indeed, the larger the quantity of oxygen which immediately surrounds the germinating seed, other things being equal, the greater will be the quantity of carbonic acid generated in a given time. Oxygen is as favourable to germination, as the presence of large quantities of carbonic acid is unfavourable; and the process will be manifestly hastened, by placin quick-lime near the seed, in order to absorb the carbonic acid as fast as it is formed. The seed at first loses in weight; but, as germination advances, and the roots and the stem acquire size and shape, the increase of mass becomes very considerable. A seed of beet-root, of the weight of $\frac{6}{100}$ of a grain, may give birth to a root weighing twenty-eight pounds. Now, without denying the influence of the soil upon the growth of a plant, it is a well-attested fact, that a seed may give birth to a plant, nay, arrive at perfect maturity, by the mere concurrence of water and air.

Carbon is the predominating principle in dried plants, and is met with in the atmosphere in the *form of* carbonic acid. Plants under the influence

of solar light, are capable of decomposing this carbonic acid, of uniting with its carbon, and restoring its oxygen to the air. The researches of Saussure show the necessity of the presence of light in order to make the carbonic acid act favourably upon vegetation. He found that young plants, under the influence of solar light, decidedly throve when the atmosphere contained as much as $\frac{1}{11}$ of carbonic acid, and that their growth was evidently more vigorous than when in common air alone; and at the conclusion of one experiment, he found almost the whole of the carbonic acid replaced by oxygen! He found, further, that the smallest addition of carbonic acid to the air, above its ordinary quantity, is injurious to plants in the shade. At night time the assimilation of the carbonic acid ceases: oxygen is no longer exhaled from the leaves of the plants; but a true chemical process commences. Oxygen is inhaled by the leaves, and carbonic acid formed at the expense of the carbon contained therein; and this acid is retained, either in part, or wholly, in proportion as the green part of the leaf is more or less plentifully provided with water.

Here, then, we find the solution of the question, how it occurs that the proportion of oxygen in the atmosphere has remained unchanged in the lapse of ages. We find the life of plants connected with that of animated nature in the most simple manner, and for *the most* wise purposes. The vegetable

world not only affords the means of nutrition for the growth and continuance of animal life, but also separates the noxious carbonic acid from the atmosphere, and is an inexhaustible source of pure oxygen, supplying to the air the loss constantly sustained by it in the support of the animal creation. As, therefore, animals exhale carbonic acid, whilst plants inspire it, the composition of the atmosphere, the medium in which both live, remains unchanged.

Water, also, is ever present in the atmosphere. I have already called your attention to the composition of water, and to some of its properties, in the chapter on the Chemistry of the Breakfast-table; but I have somewhat to add. In the state of *vapour*, water exercises a most important influence on the health of human beings and animals, and on the growth of plants. At all temperatures water rises by evaporation into the air, which, therefore, is constantly impregnated with it; accompanying it wherever it penetrates, pervading the pores in the leaves of plants, and gaining admission into the lungs and skins of animals. The quantity of vapour which the atmosphere is capable of holding, is dependant upon temperature. When fluid water is present with vapour in large proportions, the latter becomes completely moist and opaque, as in mist and in clouds. The red and golden tints of clouds appear to be owing to a peculiar property of steam. When issuing into the

atmosphere from under a pressure of from five to thirty pounds on the inch, a light appears, of a deep orange-red colour. The steam possessing this colour is mixed with air, and on the point of condensation. When the temperature of a cloud, containing vapour in large quantities, falls, a portion of the vapour is condensed, and falls in the form of *rain.* When clouds form at temperatures below 32°, the watery vapour is converted into small needle-like crystals, which re-unite with many others, and fall as *snow.* The phenomenon of *hail,* also, is caused by cold, but under different circumstances. Its formation is always attended by electricity, and it seems to be produced in a moist ascending current of air (greatly cooled by rarefaction), having an upward velocity sufficiently strong to sustain the falling hailstones, until they have attained considerable size.

From the preceding remarks, it must be obvious that it is owing solely to the high temperature of the air that the presence of water in it is not always perceptible. If you cool a portion of air, you will at once perceive the presence of water. If a decanter filled with spring-water, fresh from the well, be brought into a room, the outer surface of the decanter will immediately become covered with *dew.* And so, also, in nature. The appearance of dew always follows a fall in the temperature of the substances *on which it* is deposited. All bodies on the

earth's surface throw out heat in straight lines, every warmer to every cooler body; and thus the tendency of the surface of the earth is always towards a cooler state. When the sun shines, a body receives more rays than it sends out: its temperature, therefore, rises; when a body gives off more rays than it receives, as is the case on a cloudless night, its temperature falls; and thus the cooling of bodies occasioned by nocturnal radiation is always accompanied by a deposit of moisture upon their surface, in the form of minute globules; in fact by a fall of *dew*.

In very warm climates, the dew is so plentiful as materially to assist vegetation. When the sky is clear and calm, plants cool down during the night, and very soon show a temperature inferior to that which surrounds them. No dew is deposited on cloudy nights, as the rays thrown off by the earth are returned by the clouds, and the temperature of the air is consequently maintained. Nor does dew fall equally upon all bodies. "Different substances are endowed with the property of radiating their heat, and of thus becoming cool with different degrees of rapidity, and those substances which in the air become cool first, also attract first and most abundantly the particles of falling dew. Thus, in the cool of a summer evening, the grass-plat is wet, while the gravel-walk is dry; and the thirsty pasture and every green leaf are drinking in the

descending moisture, while the naked land and the barren highway are still unconscious of its fall. How beautiful is the contrivance by which water is thus evaporated, or distilled, as it were, into the atmosphere—largely, perhaps, from some particular spots—then diffused equably through the wide and restless air, and afterwards precipitated again in refreshing showers or in long mysterious dews! But how much more beautiful the contrivance by which the dew selects the objects on which it delights to fall; descending first on every living plant, copiously ministering to the wants of each, and expending its superfluity only on the unproductive waste!"—*Johnston.*

Nocturnal radiation is frequently destructive to vegetation in spring and autumn, by lowering the temperature several degrees below the freezing point. An unclouded sky affords the principal condition for nocturnal radiation. Before we had attained to the knowledge that bodies on the surface of the earth become cooler than the surrounding air on a clear night, it was difficult to comprehend how the flimsy coverings which gardeners throw over vegetables for their protection from injury consequent on a low temperature of the air, could be effective. The natives of Peru, who observed that it froze only when the sky was clear and calm, contrive to create artificial clouds, when they are led to apprehend a frost. They set fire to heaps of damp straw

and thus raise a cloud of smoke over their crops—a measure which Boussingault states to be a complete protection.

To water and carbonic acid, whose presence in the air is constant, though small in quantity as compared with oxygen and nitrogen, must yet be added another substance, *ammonia*. It is a compound of two elements, nitrogen and hydrogen, and is possessed of a most pungent smell, commonly known as hartshorn. In the atmosphere, however, it is contained in such minute quantities, that it is never known to communicate even the faintest odour to it. According to Fresenius, one million parts of air contain only 0·283 parts of carbonate of ammonia by day, and about twice that quantity by night. The comparative smallness of the quantity present by day, is probably owing to two causes: 1. that in the daytime more ammonia is expended in the nutriment of plants; 2. that the ammonia which accumulates during the day and night together, is dissolved and precipitated by the dew at sunrise. Be this as it may, it is certain that the ammonia of the air does supply wild plants with much of the nitrogen required for their growth. It is well known, that in the process of decay and putrefaction, ammonia is constantly evolved from all vegetable and animal matters containing nitrogen. We know, also, that salts of ammonia are products of the combustion of both wood and coal. From

many sources, and at all times, ammonia rises into the air, and plays an important part in vegetable nutrition. It is certain, not only that salts of ammonia have been discovered in the juices of many plants, but that the roots are capable of taking them up. And it is equally certain that guano, and such-like manures, owe much of their value to the large amount of ammoniacal salts which they contain.

I have now mentioned all the constituents of the atmosphere; but it is capable, nevertheless, of being impregnated with many other matters. Thus, near the sea, the air is always found to contain common salt, and, indeed, all the other constituents of sea-water. In large cities, it is more or less contaminated by the various gases evolved in the different processes of decay and putrefaction, and by the chemical operations carried on in such places.

But setting aside these trifling differences, we may well ask how it is that the air should maintain its composition so constantly? All experimentalists agree in this, that specimens of air brought from districts the most remote, from London and from New York, from Mont Blanc and from Chimborazo, preserve an absolute identity of composition. The greatest difference is in the quantity of watery vapour; this result however it would be natural to expect: but, when we consider that the atmosphere is a mere *mixture* of gases, that no affinity what-

ever exists between its various constituents, that all bodies which possess attraction or affinity for oxygen combine as easily with it as if nitrogen were not present, that every passing rain removes those gases which are the most soluble, we are at first sight completely at a loss to understand how these things can be. And when we further con-emplate the still more remarkable fact, that all the gases contained in the air are of different specific gravity, that there is as great a difference between the weights of oil and water as exists between those of nitrogen and carbonic acid, we are lost in amazement at the power of the Almighty!

Now these difficulties may be explained upon the principle of what is called the *law of the diffusion of gases.* This law (known as Graham's law), is found to be entirely independent either of specific gravity or affinity, and may be thus briefly stated: the particles of one gas, though highly repulsive to each other, do not repel those of a different kind: hence one gas acts as a vacuum with respect to another. Were it not for this law, the carbonic acid evolved in such vast quantities in our large towns would collect, and would speedily destroy their inhabitants. The foul and noxious gases which constantly arise from the numerous operations of a large city, would spread disease and pestilence around it. Were it not for this law, the *perfume of* flowers, and the sweet scent of newly-

mown hay, would not arise to fill our hearts with a sense of gladness; but would fall from their own weights on the senseless earth. Were it not for this law, the oxygen would separate from the nitrogen, and a universal conflagration, which no water could subdue, would arise on the ignition of the first fire. In fact, were it not for this law, there could be no life. Vegetation must languish and die, for want of a supply of carbonic acid, which, by this provision, is wonderfully and completely diffused throughout all the particles of air. The watery vapour, of no less importance, would not, as now, keep flexible the skin of animals, and supply parched vegetation with rains and dew. In the process of respiration, the minute cells of the lungs, in which the real aëration of the blood takes place, would not, as now, be emptied at each exhalation of the heavy carbonic acid which they contain; but the process would be, after a few minutes, suspended, and death ensue.

It is, indeed, a most necessary and beneficent law, and is well calculated to fill our minds with awe at the power, and gratitude for the goodness of that God, who, in the words of the patriarch, "Bindeth up the waters in His thick clouds, and the clouds are not rent under them."

I have thus noticed the composition and the most important properties of the air we breathe; and have, I think, prepared you for the subject with which I intend to follow up this chapter.

CHAPTER III.

CHEMISTRY OF THE ATMOSPHERE (CONTINUED).

THE CHEMISTRY OF COMBUSTION, AND OF THE ARTIFICIAL SOURCES OF LIGHT AND HEAT.

You will remember, that I have several times alluded to the fact, that the oxygen of the air plays the part of supporter of combustion. Combustion is always accompanied by the phenomenon of heat, and frequently of light. In fact the two are disposed to produce, and are probably convertible into, each other. The rays of the moon form, it is true, a supposed exception to this rule; but it will cease to be matter of wonder, that our best instruments do not indicate any heat in them, when we reflect that a single ray of the moonbeam possesses only the 1-300,000th part of the light of a solar ray of the same size!

In all ordinary cases of combustion, air is present, and all the phenomena of combustion may be explained by the sudden chemical action which ensues at high temperatures between the burning body and

the oxygen of the air. Not that any temperature can be fixed at which bodies burn or inflame in air; on the contrary, some take fire the moment they are exposed to it; others at a temperature a very little above that of summer-heat; some at a very high temperature; others again refuse to burn under any condition. The products of combustion, the result of the union between the oxygen and the burning body, are usually gaseous, and hence they escape the notice of the ordinary observer. Before we can, however, with any profit, consider the products of combustion, it behoves us well to understand the nature of those bodies which are more or less employed as sources of light and heat. And how much better prepared for this consideration we shall be, may be imagined, when I inform you that all the elements which conjoinedly constitute coal, tallow, wax, wood, stearin, street gas, and oil, are met with in the atmosphere.

I have already called your attention, in some degree, to that fundamental constituent of all sources of flame, CARBON, and have given you some notions of its immense importance. It is of universal occurrence in the animal and vegetable kingdoms, and is found largely in the mineral kingdom; it forms the chief constituent of coal; in a pure state it is met with in the diamond; graphite, or the lead of lead-pencils, is but carbon in an impure form; and, combined chemically with oxygen, as carbonic acid, it

is met with in the air, and in water, in limestone and marble combined with lime as carbonate of lime, and in not a few minerals besides. If you were to take a piece of charcoal, and keep it red hot in contact with air, until the blackness has disappeared, and nothing remains but a minute quantity of a white ash, you would find, on examining the vapour, that the carbon has merely assumed a new form by uniting with the oxygen of the air, and has become *carbonic acid* gas. The latter is of a very poisonous character; extinguishes flame as effectually as water, and is easily detected by limewater, from which it separates the lime in a solid form, as carbonate of lime or chalk. Carbonic acid, then, is not a supporter of combustion. But there yet remains to be described another combination of carbon with oxygen, commonly called carbonic oxide, which may be frequently met with. It is ever formed by the combustion of carbon, when the supply of oxygen is insufficient to produce carbonic acid; hence the lambent blue flame, which may often be seen dancing upon a coal, coke, or charcoal fire, or issuing from iron furnaces. It is fatal when inhaled. Burnt in the air, it unites with more oxygen, and forms carbonic acid.

Next in importance to CARBON, as a source of heat, is HYDROGEN. It is the lightest form of matter we know of, an equal volume of air being fourteen times *heavier* than this gas. Although it is not a sup-

porter of combustion, and is, in the absence of air, an extinguisher of flame, yet when ignited in presence of it, it burns with a blueish flame, and emits very great heat. Indeed, in an apparatus so arranged that every two volumes of this gas shall meet with one of pure oxygen, the amount of heat obtainable from such source is greater than from any other. The oxy-hydrogen flame is capable of fusing the most intractable metals, platinum being softened and melted by it as easily as gold in a furnace. The product of the union of oxygen with hydrogen in the proportions I have mentioned, is pure water. The *flame* of such a light is weak indeed; but it is believed that pure gaseous matter is not susceptible of giving out light. Certain it is, that the heat of a flame is independent of its light, and that such flame will prove to be the hottest in which hydrogen abounds. It is well known that common air may be heated to such an extent, that it will inflame pieces of wood, and yet itself remain invisible. A good instance of this is afforded by the air which issues from the chimney-glass of an argand gas-burner, which will make a thin piece of wire red-hot, even when held several inches above the flame.

To carbon and hydrogen, as sources of light and heat, must be added OXYGEN. Of this element I have little to add to what I have previously said. It may be produced artificially from a variety

of sources; but the main feature to which I have again to call your attention, is the extraordinary brilliancy with which bodies burn in it. Phosphorus, when inflamed in the atmosphere, where the oxygen is mixed with four times its volume of nitrogen, burns with a very bright light; but it is no more to be compared with the brilliancy of phosphorus, inflamed in oxygen, than is the light of the sun to that of the moon! Coiled iron-wire, once inflamed, and immersed into a jar of this gas, bursts into vivid combustion, throwing off bright scintillations, and fusing into globules of red oxide of iron, which are so hot, that they melt deeply into the glass. The combinations of oxygen with other bodies are termed oxides; the abstraction, separation, or removal of oxygen, is called reduction, or deoxydation. All the elements are capable of oxydation, and most of them at a temperature more or less high, with the evolution of heat and light. A substance incapable of further entrance into combination, such as water and carbonic acid, is called incombustible or uninflammable. All organic bodies are combustible. Whenever a body unites with oxygen, it increases by as much in weight as it has absorbed of the gas. The term, therefore, *destruction* of bodies by combustion, is incorrect, inasmuch as matter is indestructible; in fact, when we seem to destroy a candle, or a lump of coal, by burning them, *we only* compel them into new forms of combina-

tion, which being gaseous, are either immediately dissipated in air, or may be detected escaping up the chimney. When the product of combustion happens to be a solid body, as in the case of inflamed phosphorus and zinc, we can more easily believe the evidence of our senses, as we may handle and weigh the phosphoric acid and oxide of zinc thus produced.

In COAL, we see the remains of a vegetation which covered the earth before it was inhabited by man. It has probably arisen from plants and trees of an early time, which have been buried by the violent agencies of water and other causes under mighty strata of sand and clay. Here it has become slowly and partially decomposed, whilst the beds of sand and of clay have been hardened by time into sandstone and slate. The pressure of these deep strata have not only prevented the evolution of gas thus giving to the coal the property of burning with flame, but have, to a great extent, obliterated all appearance of vegetable structure, and given the substance the close and compact quality of stone. The various kinds of coal, which forms the ordinary fuel of this country, consist of carbon, hydrogen, nitrogen, and oxygen, in very varying proportions, with more or less of ash. The amount of nitrogen varies, according to Regnault, from 1½ to 2 per cent. That of carbon averages 70 per cent.

But in *order the* better to understand the chemical

nature of the changes going on, whilst the fuel is burning, we will first consider the products of the destructive distillation of coal, which furnish so valuable a source of light. The production of coal-gas, or street-gas, is a trade of great magnitude. The coal is placed in oblong cylinders of cast-iron, which are ranged in furnaces, to keep them at a red-heat, and all the volatile products are conveyed by a tube in connection with all the cylinders into a condensing vessel, kept cold by immersion in water : here all the condensible vapours, such as water, tar, ammonia, and other impurities, are retained. The coal-gas, still more or less impure from the presence of carbonic acid and sulphuretted hydrogen (the gas evolved from rotten eggs), is now passed through a mixture of slaked lime in water, in vessels called purifiers. The lime robs the gas of its impurities, and combines chemically with them, but has no affinity to the gas itself. The latter is sometimes still further purified by passing through diluted sulphuric acid, which removes all traces of ammoniacal gas, and is then transmitted for use into gasometers, whence the pipes issue for the supply of streets, shops, and private houses.

Coal-gas consists chemically of a mixture of two distinct forms of combination of hydrogen and carbon. These are light carburetted hydrogen and *olefiant* gas. The former, or light carburetted

hydrogen, occasionally occurs pent up in coal-mines, and in stagnant pools, and is the cause of frequent and fearful explosions. It is called fire-damp by miners, and is the chief constituent of the flame known by the name of Will-o'-the-Wisp. (The latter is probably kindled by the presence, in minute quantities, of inflammable phosphuretted hydrogen.) It contains less carbon than olefiant gas, and burns with less brilliancy, and a yellow flame.

When olefiant gas preponderates in coal gas, the flame is white. The heat of the flame is owing to the formation of water and carbonic acid at the expense of the oxygen of the air. The luminosity of the flame, which renders it valuable as a source of light, is owing to solid matter diffused through it, and ignited by it. You may say that you do not see any solid matter in the gas-flame as it issues from the common burner. True,—but if you depress a white saucer into the flame, you find it immediately covered with soot, or carbon, and much of the brilliancy of the light is destroyed. The cause, then, of the light, is owing to the diffusion of carbon through the flame, by which it has been heated to whiteness. That flame requires a high temperature for its existence, you have been taught by the fact that any cold substance depressed upon it removes a portion of its carbon. The great condition that must be complied with in order to obtain a bright light from *gas, is to* take care that it has a constant

supply of fresh air. This is accomplished by two methods. In the first place the gas is made to stream out of thin apertures, surrounded both internally and externally by air, as we see in the common argand burner; and in the second place, not only is the gas protected externally by the chimney-glass from any sudden gusts of cold air, but the brightness of the flame is greatly increased because a continued stream of air rushes in regularly from below the glass exactly in the proportion as the heated air streams out from above. In proportion as the draught is increased, will the flame be brighter.

Whilst yet on the subject of coal gas, let me mention another property of flame. I have said that flame requires a high temperature for its existence. By cooling it may be therefore extinguished. The experiments of Sir H. Davy upon this subject led to the construction of that most ingenious instrument, the miner's safety-lamp. If you take a piece of wire-gauze, of such finenesss as to have about thirty meshes to the square inch, and depress this quickly upon the burning gas-jet, you will find that the flame will be cut off just where it touches the gauze. The inflammable matter of the flame (much of the undecomposed gas, together with a good deal of soot), passes through the gauze. In its passage it is so far cooled as to be extinguished; the *flame therefore* is prevented from passing, although the

gas is not. If you bring a piece of lighted paper above the flame, to the upper side of the gauze, the gas will be rekindled, and burn as before. Again, by varying the experiment, and turning on an unlighted jet of gas underneath the gauze, you may kindle the flame above, and it will not pass! The cooling property of the wire-gauze is owing to its great power of conducting heat. Sir H. Davy, who is the author of these and many other experiments on flame, placed a lighted lamp within a perfect cylinder of wire-gauze, and found that although inflammable gases would pass through and could be enkindled, yet that the flame would not be communicated to the air without. The safety of these lamps depends entirely upon the perfect state of the wire-gauze.

Combustible as most kinds of coal are, they must be heated to a certain extent before they will inflame. This is accomplished by the use of the more readily combustible paper and wood. They are laid in the grate, and the coal is heaped upon them so, that the air may have sufficient access. When the coal is heated below redness, its hydrogen unites partly with its own oxygen, partly with that of the air, and escapes up the chimney in the form of steam. The heat at first is usually insufficient, and therefore a quantity of the carbon of the coal is separated from the hydrogen, with which, and with the oxygen, at a higher temperature, it would otherwise have been *combined, and* passes likewise up the chimney.

At length, after the heat has been somewhat increased, the olefiant and other gases burst out into flame, continuing as long as the supply of the hydrogen lasts. As long as there is any carbon, the coals retain their glow, and continue to burn though no longer with flame, until nothing remain in the grate but the incombustible ashes, which consist mainly of silex, gypsum, and clay.

And now, with reference to the actual combustion of the fuel, we know that to be due to its union with oxygen. Of the properties of carbonic acid, of its power of extinguishing flame, and its heavy character, I have already spoken. Its weight indeed would very seriously interfere with the burning of the coal, were it not for the important fact that the heat evolved by the combustion itself, is the very agent by which it is carried off as fast as it is produced. When this, or any other gas, is heated, its particles expand; its actual weight remains unchanged, but it occupies a larger space. When a portion of air is heated in the open atmosphere, it expands and rises upwards, not because of itself it has any tendency to rise, but because the heavier cold air around it displaces it, and makes it ascend. A flame ascends simply because the heat given out by it expands the surrounding air, and makes it lighter than air usually is. The heat evolved ensures, not only the removal of the carbonic acid, *but also* causes a circulation of fresh air through

the burning fuel. In a good grate, therefore, all these gases are carried off up the chimney, upon the draught of which the burning of the fire greatly depends. A fire, therefore, serves the purposes both of ventilation and heat. When the weather is cold, we make a large fire, and thus, of course, expand a larger volume of air than usual, in consequence of which, a larger amount of cold air will rush into the room. The ascent of smoke then being dependent upon the admission of colder air, the fire will only burn well, and the chimney draw in proportion as we allow it to enter.

With reference to the waste of fuel, which goes on when much of it is allowed to escape in the form of smoke, it arises solely from insufficient access of air, and might be, if not entirely, at least in great part, prevented.

As to the temperature of a fire, I may mention that a dull red-heat, visible in daylight, is probably equal to 1,000°, a full red-heat to 1,200°, an orange-heat to 1,700°, and a white heat to 3,000°. The latter is rarely, if ever, attainable in a common fireplace.

PEAT and TURF consist mainly of the remains of vegetables, having undergone comparatively little change.

WOOD may be said to consist of nearly equal weights of carbon and the elements of water. From this it may be inferred that wood fires will not only

burn with much flame and little smoke, but will give out intense heat, and waste very fast. There is also a very peculiar odour which may be said to accompany the burning of wood. The products of the destructive distillation of wood are very different from those of coal, and wood-naphtha and vinegar being among the products, it may be expected that the vapours of the burning wood will, according to the temperature of the fire, more or less partake of the odour of these.

Common charcoal, employed as fuel, is usually made of oak, chestnut, elm, beech, or ashwood. Young wood fortunately affords better charcoal than the finest timber. The billets are formed into a conical pile, which, being covered with earth or clay, is suffered to burn with a limited access of air. The oxygen and the hydrogen of the wood combine to form water, and little of the carbon is consumed. Wood charcoal contains about 2 per cent. of salts, which remain in the form of ash, after combustion, but the quantity and quality vary according to the nature of the tree.

Having thus far drawn your attention to fuel, I shall now re-divert it towards the subject of flame. In the chemistry of a candle, we must first consider the various materials of which candles are formed. The best candles are made of wax, a substance either collected by bees from the pollen and other parts of flowers, or produced by those insects from sugar.

As obtained fresh from the honeycomb, it is of a yellow colour, and possessed of a peculiar smell. Exposed in thin layers to the action of sunlight, it loses both smell and colour. By the action of hot alcohol, wax may be separated into two distinct substances, *cerine* and *myricine*, the exact composition of which is unknown.

SPERMACETI is found in certain hollows in the head of the various species of delphinus. During the life of the fish, it is dissolved in spermaceti oil, but at death it separates in hard crystalline masses. Freed entirely from the oil, it may be said to consist of *cetine*, a crystalline substance of pearly lustre.

TALLOW is the fat of oxen and sheep. It contains *glycerine* in combination with certain organic acids. This glycerine is the sweet principle of oils and fats. When pure and freed from water, it forms a syrupy liquid, of a sickly sweet taste. It is rather heavier than water, in which it may be dissolved to any extent. It burns with a bright flame.

In tallow, this glycerine is combined with stearic, margaric, and oleic acids. Such compounds, whether they be found in *oils* or *fats*, are usually called *stearine*, *margarine*, and *oleine*. Where stearine, or, to speak correctly, stearate of glycerine, predominates, the fat is very firm. If margarine abounds, it is soft, like lard ; if oleine, it is liquid.

Alkalies, such as potash and soda, combine with these acids, and set the glycerine at liberty. This

process is called saponification, because the new compounds have the properties of soap.

STEARINE, or stearate of glycerine, a material much employed, when mixed with a little wax, in making composite candles, is prepared by a process of saponification. Common tallow is boiled with potash; the stearate of potash thus formed is precipitated by chloride of calcium as stearate of lime. The latter is decomposed by a mineral acid, and stearine thus resulting, is pressed between warm plates, and has the appearance of a hard wax-like mass.

Margarine, or margarate of glycerine, is likewise a constituent of olive oil, human fat, and in small quantities of most fats and oils. It has the aspect of a soft fat.

Oleine, or oleate of glycerine, is the chief ingredient in oils, and gives to them their liquid character. It abounds to that extent in almond oil, that its properties may be best studied therein. I do not propose to dwell further upon this rather difficult subject. I have offered you sufficient information to awaken your attention; and should you desire further knowledge, you may obtain it from any of the numerous modern works on chemistry. Nor shall I enter into the mechanical process of making candles from wax, stearine, tallow, and spermaceti, as no part of it requires explanation.

All these materials inflame of themselves at a very

high temperature, and burn with a very bright flame. But the temperature which renders them gaseous, decomposes them, and they emit a most suffocating odour. It must therefore be evident that they could not subserve the purpose of lighting a room unless some contrivance be accomplished by which the melted materials should undergo complete combustion. Fortunately they all melt at a comparatively low temperature, and act as liquids. By the use of wicks we are enabled to effect the two desiderata. They are usually made of twisted cotton, the separate threads of which act as narrow tubes, and draw up the oil or melted tallow by what is called capillary attraction. These wicks, in composition, partake much of the character of dry wood : they require a larger amount of oxygen than they ordinarily obtain, and therefore need *snuffing*, because the whole of the carbon can never be consumed. In order to supersede the necessity for snuffers, wicks are now prepared, in which either a thin metallic wire is interwoven, or they are steeped in solutions of nitrate of bismuth or lead, salts which contain large amounts of oxygen, which at the high temperature of the ignited wick, oxidizes and consumes it. Wicks are sometimes made of asbestos, a mineral substance upon which fire possesses no action : even thin glass tubes are used, in oil-lamps, to supply their place.

Before we consider the flame of a candle, it will

be as well to clear the way of every difficulty. All the sources of light, which we have so lately enumerated, consist only of carbon, hydrogen, and oxygen, in certain fixed proportions. The affinity of the hydrogen for the oxygen is greater than that of the carbon. The gases which are obtained from the tallow or wax, in passing through the inflamed wick, are very similar to street gas. They are mixtures of olefiant gas with light carburetted hydrogen, and I shall simply call them gas. The outer part of the flame of a candle meets with the largest amount of atmospheric air, without which there can be no combustion in the ordinary acceptation of the word.

In the flames of tallow, wax, and oil, as in that of gas, we have seen that the light is owing to finely-divided carbon, heated to whiteness. The process is as follows: the melted tallow, or wax, is drawn by capillary attraction into the burning wick, there it is decomposed, converted into gas, which rises in a conical form, and is of a temperature sufficiently high to unite with the oxygen of the air, and corresponding to a white heat. But this combustion is superficial, as the flame incloses a portion of heated vapour, which cannot burn for want of oxygen. In the cone we may distinguish three parts. In the *centre* a dark cone of gas (decomposed tallow, or wax), *surrounded* by a luminous mantle, consisting of inflamed hydrogen, with which white-hot carbon *is intimately* mingled, and at the *outside* by a thin,

scarcely luminous, cloak, in which the carbon unites with the air.

When the combustion of a tallow, or wax-candle is complete, nothing but carbonic acid and water are given out to the air. *There is no smell.* But if a lighted candle, or lamp, be carried quickly through the air, it smokes and gives out an unpleasant smell, because the temperature of the flame is so much lowered that it can no longer consume all the carbon, or all the vapour, of the decomposed tallow, wax, or oil.

Camphine, or rectified oil of turpentine, is a compound very similar to naphtha. It contains no oxygen, and the amount of carbon, as compared with its hydrogen, is so great that no ordinary wick would effect its combustion. But by the application of the *principle* of the argand-burner, and the use of a chimney-glass, sufficient air can be supplied to the circular wick as to cause the production of the most brilliant and the most perfect light with which we are acquainted.

CHAPTER IV.

ON THE CHEMISTRY OF FERMENTATION.

IT may be laid down as a general principle in chemistry, that the more simple a substance is, as to its constitution, the more stable—the less liable to decomposition, or to rearrangement of its parts—will it be, and *vice versâ*. The actual number of substances capable of undergoing fermentation, is exceedingly small, yet are they all most complex in constitution. In the chapter on Breakfast-table Chemistry all of them are mentioned incidentally; and, in fact, it is impossible to speak of the theory of bread-baking without entering slightly upon the subject of fermentation.

STARCH, CANE-SUGAR, and GRAPE-SUGAR are the compounds which are capable of vinous fermentation, that is to say, of undergoing a process in which spirits of wine, or alcohol, is formed, as is the case in the making of wine and beer. Even starch and *cane-sugar* must first be converted into grape-sugar

before they can ferment, and even the latter changes only under the influence of a so-called *ferment.*

It will be remembered that grape-sugar is not peculiar to the fruit of the vine, but to all fruits, of which it is the sweetening principle, and that GLUCOSE (from γλύκυς, sweet), is the more appropriate term. It is less soluble in water, and less sweet, than cane-sugar, and crystallises in a different manner. A solution of perfectly pure grape-sugar in water, may be kept for a length of time, without the formation of any alcohol. But if it be mixed with white of egg, flour-paste, or blood, in a *state of decomposition*, then alcohol and carbonic acid will be formed at the expense of the sugar. Now, although sugar contains neither alcohol nor carbonic acid, yet it contains the elements of which these substances consist. The composition of grape-sugar is—

Carbon	36·4
Hydrogen	7·0
Oxygen	56·6
	100·0

Pure or absolute alcohol, as it is called, and carbonic acid, the bodies which are produced in the process of fermentation, consist of—

	Alcohol.	Water.	Carbonic Acid.
Carbon . .	52·19		27·27
Hydrogen .	13·02	11·1	
Oxygen . .	34·79	88·9	72·73
	100·00	100·0	100·00

One hundred parts of grape-sugar may, then, be said to consist of—

Alcohol	46·46
Carbonic Acid	44·45
Water	9·09
	100·00

I have said that solutions of pure sugar cannot ferment, but in nature none such exist. The juices of all fruits contain within themselves the elements necessary for the production of vinous fermentation. Now, it may be fairly asked, what is understood by a ferment? It is a certain form of matter in a state of change, which it is capable of communicating. All ferments contain nitrogen, and are in a state of decomposition. Fresh white of egg, for example, is not in itself a ferment; but when, by the action of the air, it becomes putrid, an alteration in its character takes place. Not only does it become changed in character, but it is capable of inducing a similar kind of change in compound bodies such as sugar, with which it may be brought into contact. Ferments are, therefore, contagious; or, in other words, capable of propagating their state of change. Fermentation is a process of change, occasioned by a new arrangement of the elements of a compound.

WINE.

The juice of the grape consists mainly of water holding in solution grape-sugar, albumen, or white of egg, cream of tartar, a colouring matter, an oil, and a little tannin. It is obvious, therefore, that grape-juice can ferment of itself. The proportions in which the various constituents of the juice exist, vary according to climate, culture, and the nature of the soil. Few crops are so much at the mercy of the atmosphere as the vine; even in the most favourably situated vineyards, it is rare that vines of equal quality and flavour are produced in two successive years. A hot summer is naturally favourable to the vine; but besides the sustained heat, which is necessary during the whole year's growth, it would appear that a mild autumn is a necessary condition to the ripening of grapes. The cultivation of the vine would be altogether ruinous, were it not for the circumstance that the value of wine increased in a much greater ratio than its quality, so that one good year often indemnifies the grower for many bad, and that the vine grows and thrives in situations where it would be difficult to rear any thing else. The produce of a vineyard depends also upon its age. Official documents, whilst they give the mean produce of the vine, for the whole of France, at 171 gallons per acre, state the whole of the wine produced over the country at 976,906,414

gallons. The produce of the vineyards of the German States brought to market, appears to be 59,180,000 gallons. (Boussingault.)

In making wine, the *juice* of the grape is put into vats, or barrels, and left to itself. The albumen naturally contained therein, acted upon by the oxygen of the air, soon decomposes, and acts as a ferment upon the sugar. Alcohol is formed in the liquid, which becomes changed into wine, and carbonic acid is given off in such enormous quantities as to require some care in the overlookers. After fermentation has once set in, the access of air is not only no longer necessary, but is rather injurious than otherwise. In some countries the gas is passed, by means of a tube connected with the spunt of the barrel, into potash, or soda-ash, in solution, and thus, not only is the poisonous carbonic acid removed from the air, but a useful salt (the so-called bi-carbonate of potash, or soda) is obtained by its union with the potash, or soda.

I have said that grape-juice contains cream of tartar. This acid salt, though soluble in water, is insoluble in alcohol. As fast, therefore, as alcohol is formed, at the expense of the sugar, does this salt separate in form of a hard, crystalline substance, from which all the cream of tartar of commerce is obtained. In good vintages, when the sugar predominates, the formation of alcohol proceeds to such extent, that the great bulk of the salt is removed;

but in bad vintages much of it remains in the wine, rendering it *sour*.

Now, just as the juice of the grape contains an acid salt, so does the juice of gooseberries, currants, and elderberries, from which home-made wines are prepared, though in them it is of a different character. The malic (from malus, an apple, because first discovered in apples) and citric (from citrus, a citron or lemon), acids contained therein, in combination with potash, are not affected by any quantity of alcohol, because they are equally soluble in water and alcohol, and thus, however disguised with excess of sugar, these home-made wines are very unwholesome for many persons.

When the quantity of sugar predominates over that of the albumen or ferment, the result is a more or less *sweet* wine. But when the ferment abounds, the wine has a *dry* taste.

If the fermentation of grape-juice be checked before it is complete, and the wine bottled, the process will be continued. Carbonic acid gas being disengaged under considerable pressure is retained in the wine, and thus are obtained those refreshing wines, Champagne, sparkling Moselle, and Hock, &c.

The colouring matter of the grape resides in the skins. The *juice* of both red and white grapes is nearly colourless, because the colouring of the skin is not soluble in water. But it *is* soluble in alcohol. If, therefore, *red* wine is to be made, the expressed

juice is allowed to ferment in contact with the skins, until the formation of alcohol has drawn out their colouring-matter. The colour of dark sherry is artificial, being derived from caramel, or burnt sugar.

The quantity of alcohol contained in wines varies. Port wine and sherry contain sometimes as much as twenty-five per cent., sometimes only sixteen per cent. The light wines of Germany and France contain from ten to fifteen per cent. Wine, like beer and spirits, as is well known, owes its intoxicating character to *alcohol.*

Absolute alcohol, or *pure alcohol,* which may be obtained by distilling the spirits of wine of commerce with half its weight of quick-lime, is a colourless, limped liquid, of an agreeable, though somewhat pungent, taste and smell. Its specific gravity is only ¾ that of water, for which it possesses great attraction. It absorbs watery vapour from the air, and from moist membranes, or any similar substances immersed in it. It burns with a pale blue flame, and is, next to water, the best solvent with which we are acquainted.

CYDER AND PERRY.

A substitute for wine is found sometimes in the fermented juice of apples and pears. The fruit is shaken from the trees, and piled up in large casks *placed in* cellars. It is crushed about two months

after it is gathered, and the pulp is left for ten or twelve hours soaking in the juice, in order to give to the cyder that rusty, yellow colour which is so much esteemed. The pulp is then pressed, and the juice run into large vats, in which it undergoes fermentation. After the latter process has proceeded for a month, the liquor is put into smaller barrels, in which the fermentation goes on more slowly. In time, long or short, according to the temperature of the cellar, the whole of the sugar is changed into alcohol, and an agreeable, though, to some persons, for reasons which have already been pointed out, very unwholesome, beverage is obtained.

BEER, ALE, AND PORTER.

In the production of beer the sugar is derived from the *malt*. Not that the barley contains much sugar, but, by a singular process, the starch passes into sugar. The operation of malting is performed by steeping the barley in water, until the grains become swollen and soft; then piling it in a heap, to favour the elevation of temperature caused by absorption of oxygen. Afterwards it is spread upon the floor, and, to prevent unequal heating, turned from time to time. As soon as the sprouting of the seed has sufficiently proceeded, it is quickly dried, to destroy its vitality. By this operation, the nature of the starch becomes altered; four times the amount

of sugar, and three times the amount of gum, originally existing in the barley, are now to be found in the malt. This change has been accomplished by means of the "*diastase*," brought into action by the germinating of the barley. The composition of this substance is unknown; but that it partakes of the nature of albuminous substances, and contains nitrogen, is certain. It is likewise certain that the starch, which is formed when the vegetative power of plants is most active, is dissolved, and made ready for use by this very diastase, which exists in all seeds and buds.

If a little malt be infused in warm water it will convert a very large amount of starch, first into soluble starch, or dextrine, and subsequently into sugar. To prove this fact, it is sufficient to mix some gelatinous starch with a small quantity of malt infusion, exposing the whole to a gentle heat. In a few minutes it becomes thin, like water, and, after a few hours, will be found to contain glucose, or grape-sugar, and to be sweet to the taste.

In the manufacture of *beer*, the malt, thus prepared, is ground and infused in the so-called *mash-tun*, in rather more than its bulk of water, of the temperature of 180°, and exhausted by repeated washings with fresh portions of water. Thus the easily soluble diastase has time to act upon the undissolved starch of the grain, and to convert it into *dextrine* and sugar. The liquor, strained from the

malt-husks, is called the *wort*. This is boiled with hops, by which the so-called *lupuline*, a bitter resinous principle, and, an essential oil, are extracted. The object of the hops, is to cloak the sweetness by a pleasant bitter, and to give to the malt liquor more durable properties. When the wort has been boiled sufficiently, it is thrown into large, shallow *coolers*, in which it is cooled as quickly as possible; it is then suffered to run into the fermenting vat, having been previously mixed with a small quantity of *yeast*. This is a substance which collects, as a scum and sediment, during the fermentation of the wort, and is derived from the changes which the gluten and albumen of the malt sustain by contact with oxygen from the air. The addition of the yeast instantly induces vinous fermentation. A great amount of froth is thrown up, arising from the escape of carbonic acid gas; the liquor loses much of its sweetness; and from being turbid, becomes clear, acquires a new taste and intoxicating properties from the formation of alcohol. The fermentation is stopped by separating the yeast, and drawing off the beer into casks.

Porter derives its colour from highly-dried, or charred, malt, the caramel of which communicates the colour. It contains about 4¼ per cent. of alcohol, whilst Burton ale contains 8½ per cent. *Small beer* contains but 1¼ per cent. of alcohol, and is a very wholesome beverage.

ARDENT SPIRITS.

THE chemistry of the manufacture of these is so similar to that of brewing, or, indeed, of the vinous fermentation in general, that little remains to be said. The distiller, who prepares spirit from grain, uses a very large quantity of *grain* with the malt, the diastase of which converts the starch thereof first into dextrine and then into glucose. The wort, or *wash*, as it is called in the language of the trade, is brought to ferment as quickly as possible, by considerable doses of yeast, and is then distilled. *Whiskey* is prepared from barley and oats. Highland whiskey and Irish potteen seem to derive their flavour from the malt being made and dried with peat, which gives out minute quantities of creosote and volatile oils. From the fermented juice of the sugar-cane we obtain *rum*. It must, however, be remembered that the sugar must first pass into glucose before fermentation can commence. *Brandy*, a word derived from the German, signifying burnt wine, is made from wine, and coloured with caramel, or burnt sugar. *Gin*, *Hollands*, and *Scheidam* are distilled from barley, and flavoured with juniper-berries, turpentine, and other substances. The two latter spirits derive their names from the places where they are prepared. In Bengal and China, spirits are made from rice, a grain containing a larger amount of starch than any other natural pro-

duct. *Arrack* is a spirit of the kind, and is characterised by the excessive amount of alcohol which it contains.

The amount of alcohol contained in gin, brandy, rum, and whiskey, varies from 40 to 50 per cent. The various flavours are due to essential oils, either generated by the act of fermentation or purposely added.

Vinous fermentation may be induced even in milk, and a spirit is prepared from it in some few places. There is every reason for believing that the lactine, or sugar of milk, first passes into glucose before the alcoholic fermentation commences. Certain it is that the lactine disappears in milk exposed to a proper temperature, with the same phenomena as characterise the fermentation of the other sugars; carbonic acid is disengaged and alcohol left in the liquid.

But every one knows that milk turns sour on exposure to air, at the ordinary temperature. The caseine of the milk, by combining with oxygen from the air, passes into a state of decomposition, forming a ferment, which induces the so-called LACTIC ACID FERMENTATION. The acid which is found in the fermented juice of beet-root, carrots and turnips, in sour-krout, and in several animal liquids, is nearly pure lactic acid. The *state* of decomposition in which the ferment exists, induces either the

lactic acid or the vinous fermentation. Thus the glutino-albuminous matter of malt, when suffered to putrify in water for a few days, acquires the power of converting the accompanying sugar into lactic acid, while, in a more advanced state of decomposition, it converts the sugar into alcohol. And again, if wheaten flour be made into a paste with water, and left four or five days in a warm place, it becomes a *lactic acid ferment:* if left two or three days longer, until it has become more putrid, it becomes true *vinous ferment.*

The formula of alcohol is $C^4 H^6 O+HO$. By oxidation, alcohol may be converted into *acetic acid,* or pure vinegar. If, for example, a little yeast be mixed with dilute spirits, and *exposed to the air,* acetic acid will be the result. All liquids capable of the vinous fermentation may be made to produce vinegar. In all such liquors, the sugar is first, by fermentation, converted into alcohol, and afterwards, by oxidation, into acetic acid.

The process used to be called the ACETOUS, or ACETIC ACID FERMENTATION, but it has nothing in common with the vinous fermentation. The presence of air is absolutely essential to the former, while the latter may, when once commenced, be better carried on with exclusion of it. The nature of the formation of acetic acid from alcohol is very intelligible. It is formed from it by the substitution

of two equivalents of oxygen for two equivalents of hydrogen. Thus—

Alcohol . . . . $C^4 H^5 O + HO$
Acetic acid (strongest) $C^4 H^3 O^3 + HO$

Pure alcohol will no more become acetic acid by simple exposure to air, than will a solution of pure sugar change into alcohol and carbonic acid. A ferment is necessary, which only acts by the power it possesses of causing the alcohol to obtain oxygen from the air. In fermented liquors, the alcohol being mixed with certain organic substances, at a proper temperature, quickly disappears, and is replaced by acetic acid. In such cases the ferment absorbs oxygen from the air, and transfers it to the alcohol.

The best vinegar is made from wine. In wine-countries inferior wines are employed for the purpose. The wine is mixed with a little vinegar, and exposed to the air in casks, partly filled with the pressed husks of grapes. From time to time, the liquid is drawn off below, air supplies its place, the husks become warm by absorbing oxygen, which they yield to the alcohol when the liquid is again poured into the vessel. This process is repeated until the vinegar is made. Its strength may be indefinitely increased by the addition of more or less brandy to the wine.

Acetic acid is frequently manufactured by the so-called *quick vinegar method*. Casks, perforated to

admit air, are filled with beech-wood shavings, moistened with vinegar. A mixture of one part of spirits, five of water, and $\frac{1}{1000}$ part of yeast, or honey, is allowed to drop continuously through the casks: the temperature rises to 100°, and the whole of the spirit is, in 26 to 36 hours, converted into vinegar, by passing two or three times through the shavings. Vinegar is also made from sugar, from beer, and from cider, by the aid of the various combinations of circumstances which have already been mentioned. Free access of air, a temperature not below 85°, exposure of a large surface of liquid, facilitate the oxidation of alcohol, and the production of vinegar.

But besides the oxidation of alcohol there is another source of vinegar—viz., distilling hard wood, as oak and beech, in iron cylinders. The flavour of *wood-vinegar* is peculiar, reminding one slightly of creosote.

Pure acetic acid is a clear, colourless liquid, very sour and pungent, and miscible in all proportions with water. The flavour of the best kinds of vinegar is due to *acetic ether.* The vinegars from wine, beer, and malt, contain, in addition to acetic ether, all the foreign matters pertaining to these various liquids. (Liebig.)

It has been thought desirable to devote a separate chapter to the consideration of the Chemistry of *Fermentation*, partly because of the great interest

it possesses as a branch of household chemistry, and partly on account of the important position which the manufacture of fermented liquors occupies in all civilized communities. From the earliest times of which we possess records, the application of the principle of fermentation, to the preparation of beverages of more or less intoxicating qualities, seems to have been generally understood. Like all other gifts of God to his creatures, that of wine, "that maketh glad the heart of man," has been greatly abused; nevertheless, though there are many philanthropists who would, on that account, entirely banish from society the use of all fermented liquors, with the exception, perhaps, of vinegar alone, it seems scarcely to admit of doubt that, used in moderation, they add materially to the reasonable enjoyment of mankind. At any rate, as long as they occupy the prominence among articles of consumption which they unquestionably do at the present day, a few pages devoted to their consideration can scarcely be thought out of place in a work like the present. The consideration of the chemistry of fermented liquors, moreover, will form a not unnatural introduction to that of the dinner-table, of which they form so important an adjunct, and which we propose to consider in our next chapter.

CHAPTER V.

DINNER-TABLE CHEMISTRY.

WITH the chemical nature of water, and with some of its properties, the preceding chapters will have made my readers familiar. But it will not be out of place to add somewhat more to what has been already said.

A water, to be good for drinking, should have the following qualifications:—Bright and clear as crystal, when poured into a tumbler, it should sparkle with the gases rising through. Oxygen and carbonic acid gas, which communicate to water its refreshing and thirst-quenching properties, should be both present, and for this reason water should neither stand long in a warm room, or in sun-light, or be drawn long before wanted. It should possess no decided taste. Hard water contains a greater or less quantity of the salts of lime, more chiefly of sulphate of lime (gypsum) and of carbonate of lime (chalk held in solution by carbonic acid), which act injuriously upon some constitutions. Water which *has a flat* taste, though far preferable to hard water,

is not sufficiently refreshing, and hence an inordinate quantity must be imbibed for the purpose of quenching the thirst. Good water should but very slightly curdle soap, and should form an immediate lather with it. If a water can be obtained which cattle drink of readily, no hesitation need be felt about its quality.

Of the quantity of water contained in vegetables, fruits, and meat, few are well-informed; and, as it would be impossible to speak of the nutritive value of the various kinds of food without taking into account the water they contain, I have drawn up the subjoined Table, showing the proportions contained in the fruits and vegetables most in use:—

	Per cent. of Water.
Common mushrooms contain .	96·00
Cabbages	92·00
Green-top turnips	90·00
Carrots	87·60
Beet-roots } Champignons } Milk }	87·00
Kohlrabi	86·00
White Swede turnips	85·00
Pears	83·90
Currants	81·30
Peaches	80·20
Parsnips	79·40

	Per cent. of Water.
Artichokes contain	79·20
Flesh	from 76·0 to 79·00
Potatoes, Yams	75·00
Cherries	74·90
Apricots	74·40
Greengages	71·00
Sweet potatoes	59·00
Kidney-beans	23·00
Haricots	16·00
Beans	14·50
Peas	13·00
Rice	12·50
Lentils	12·00
Wheaten-flour	10·00
Indian Corn or Maize	6·00

It will be seen from the above, that flesh, corresponding in composition to the flesh of our bodies, contains 79 per cent. of water; and I think that the quantity of water drunk at the dinner-table should correspond as nearly as possible with this proportion. If our food be dry, the water drunk should be in quantity sufficient to bring the total amount up to 79 per cent.; if, on the contrary, water abound in our diet, then but little need be imbibed. Any person with a tendency to become *stout*, should restrict himself in the use of water,

beer, and, unless his system has been impaired, of all intoxicating liquors.

The moderate use of wines, or malt liquor, at dinner, is in nowise to be discouraged, except in the young. It must be a very exceptional case when the digestive organs of a growing person require a stimulus, and none such should indulge in even small quantities of fermented liquors, except by medical advice. I would only except from this rule the use of weak table-beer. It is impossible to specify the exact circumstances under which it may be beneficial to take a moderate allowance of alcoholic stimulus for the purpose of promoting either mental or bodily vigour. The Bible, in recommending wine as a gift of God, proves its capability of being put to legitimate uses. These uses are clearly legitimate, only so far as that they minister to health, energy, and virtue. Alcohol acts directly on the lining of the stomach, and its habitual employment *in excess* keeps this membrane in a state of irritation, amounting almost to inflammation: it destroys digestion and appetite, produces fœtid breath, and incapacitates from mental exertion, induces sloth, and a deadening of the moral faculties, premature disease, and death.

We have seen that the proportion of water in our kitchen vegetables bears some relation to the quantity contained in flesh; and that their value varies accordingly. The greater part of our vegetables

have originally come from southern climates, chiefly from Italy; and the number of them has increased prodigiously in the course of the last two centuries. The kitchen-gardens of England were, until about the end of the sixteenth century, as scantily supplied with vegetables as the pleasure-grounds were with shrubs and flowers. "It was not," says Hume, "till the end of the reign of Henry VIII., that any salads, carrots, turnips, or other edible roots, were produced in England." The little of these vegetables that was used was imported from Holland and Flanders, and Queen Catherine, when she wanted a salad, was obliged to despatch a messenger thither on purpose. The fruits used by our ancestors were neither numerous nor good. Gooseberries, strawberries, and currants, indifferently good apples and pears, and decidedly bad cherries and plums, were about all. The most important vegetable of the present day, the potato, was brought to England in 1586; but its culture for the next century must have been but partial, as the market price was 1s. per lb. Broccoli and cauliflower were introduced about the end of the sixteenth century from the Levant into Italy, and in the end of the seventeenth into England. The turnip was in cultivation in the sixteenth century; and it is stated, that when, in the years 1629 and 1630, there was a dearth in England, very good white bread was made of boiled turnips *kneaded* up with an equal quantity of wheaten *flour.*

A most important ingredient of all vegetables, of unripe fruit, of the crust of pie and pudding, and of bread, is STARCH, known also to chemists under the various names of amylum, fecula, amiline, amidine. It is contained in the cells of vegetables, in the form of small white granules, which have no crystalline structure. These globules vary much in size and form, so much so indeed, that in the different species of vegetables they may be distinguished by a practised eye. A character, however, which is common to the majority of *feculæ*, (for thus are the granules technically distinguished) is a roundness of contour, when their particles have not been compressed by their contact in contiguous cells. Microscopical as well as chemical researches show that starch is homogeneous in properties as in composition; that its globules are composed of concentric layers, the external layers of which have exactly the same character as the internal. At page 19, among other properties of starch, its atomic constitution has been already noticed. In its greatest state of purity it may be said to consist of—

Carbon, . . .	44.9
Hydrogen, . .	6.3
Oxygen, . . .	48.8
	100.0

Starch retains water with considerable force: the

quantity retained varying with the temperature at which the drying is accomplished. Thus, the starch in potatoes, which is moist and porous, even when subjected to strong pressure, still retains 45 per cent. of water. That of the shops contains 18 per cent. It is not difficult to understand why potatoes and rice should increase in bulk when boiled, when we reflect that the starch-granules, in boiling, swell to about thirty times their original size. Plants vary much, as to the quantity of starch contained in them, their bulbs and their seed. Thus we find in:—

	Per cent. of Starch.
Rice flour,	. . 85
Maize,	. . . 71
Wheat flour,	from 39 to 77
Peas,	. . . 47
Haricots	. . . 41
Lentils,	. . . 40
Potatoes,	. from 12 to 23
Parsnips,	. . . 6

Several varieties of starch are employed for making puddings, and other light dishes.

In the Moluccas and Philippine Islands, grows a description of palm which yields a form of starch. The pith or marrow of these palms is dried, and when sifted presents itself in the form of grains, which are the genuine SAGO of commerce.

ARROW-ROOT, which derives its name from the root

of the *Maranta arundinacea*, owing to its supposed efficacy in counteracting the effects of wounds caused by poisoned arrows, is extracted, by a mechanical process, from the roots, when about ten or twelve months old. In Bermuda the roots are first deprived of their paper-like scales, and then rasped by a kind of wheel-rasp, and the starch well washed through sieves, and carefully dried. The process varies in Jamaica and at St. Vincent, but not materially. When pure, it has a dull and opaque-white colour, and crackles when pressed between the fingers. There are various kinds of spurious arrow-root in the market; many of the so-called "genuine" kinds are made from, or largely adulterated with, potato, and, although not unwholesome, they are not nearly as nutritious as real arrow-root.

The *Manihot utilissima*, which is found in South America, has very large roots, rich in starch, from which Tapioca and Cassava are obtained. Tapioca differs from cassava only in being a purer kind of starch: the latter, however, is the more nutritious.

Arrow-root, sago, tapioca, and cassava, all contain a substance besides starch, which, although its amount never rises above 3½ per cent., is highly important. I allude to albumen, which has already been described at pp. 21 and 26 of this work. Starch, important as it is, would be a very unprofitable kind of food, were it not always associated with albumen, or a similar nitrogenized substance, which

subserves the same purpose. By the process of boiling, the starch-granules become simply, though greatly, expanded: arrow-root, for instance, in boiling water, quickly loses its whiteness and opacity, becomes transparent, and the whole of the water seems converted into a thick jelly-like mass. In the baking of a sago or tapioca pudding, there is no doubt that a portion of the starch becomes converted into dextrine, as in the case of bread-baking. The use of milk instead of water in provisions, where starch abounds, tends to render them more tasty as well as more nutritious.

Some vegetables—as, for instance, turnips and carrots—contain no starch, but a principle not unlike it, to which chemists have given the name of PECTIC ACID. The juices of apples, gooseberries, currants, &c., contain a jelly, resembling isinglass when pure, to which the name PECTINE attaches. Pectic acid, in the two vegetables just mentioned, amounts respectively to 2 and 5 per cent.

The composition of pectine and pectic acid is as follows:

	Pectine.	Pectic Acid.
Carbon	42·9	42·8
Hydrogen . . .	5·1	5·2
Oxygen	52·0	52·0
	100·0	100·0

From this it will be seen that the elementary composition of both is identical.

Sugar, too, is to be found in almost every part of vegetables. It is less abundant, however, in seeds, than in any other part. On account of its solubility in water, vegetables containing much of it, such as potatoes, turnips, and carrots, should be steamed rather than boiled. Both cane-sugar and grape-sugar have been met with mixed in vegetables. It has been already pointed out how starch and cane-sugar may be converted into grape-sugar or glucose, but the inverse has not, *as yet*, been accomplished. At no distant period, we may expect to see factories established in England for the preparation from potato-starch of a cane-sugar which shall rival the best produce of the West Indies.

To the same class of ternary compounds, found in vegetables—that is to say, of such as consist of the three elements, carbon, hydrogen, and oxygen, to which starch, sugar, pectine, pectic acid, gum, and oil, belong—must be added WOODY FIBRE and CELLULAR TISSUE. Woody fibre consists, in fact, of two substances: one, the cellular substance, constituting the tissue of wood, and of all the organs of plants; the other, the woody substance properly so called, filling, and in some sort consolidating, the cells. Cellular tissue is identical in composition with starch. Thus:—

	Cellular tissue of Starch.	Apple.	Mushroom.
Carbon . . .	44·9	44·7	44·5
Hydrogen . .	6·3	6·1	6·7
Oxygen . . .	48·8	49.2	48·8
	100·0	100·0	100·0

Now, the composition of woody fibre differs considerably from that of cellular tissue ; it is richer in carbon. The elementary composition is:

Carbon	53·8
Hydrogen	6·0
Oxygen	40.2
	100.0

In the general acceptation of the term, the name of *wood* is applied to the solid part of the trunk and branches. We cannot, however, thus limit the definition of wood. The stringy substance in the stalks of cabbage, of old turnips, &c., contains it. We can now understand better than before the changes which the cells of vegetables experience as they grow old. It is by the appearance of the encrusting woody matter that their thin, transparent, and, at first colourless walls, thicken, become opaque, and acquire strength. It need scarcely be said, that the production of insoluble, indigestible woody fibre, does not add to the value of an

esculent, but rather detracts from it; besides the actual discomfort in eating a tough vegetable, its nutritive value is greatly reduced by old age.

I must not omit to notice the quaternary compounds, or those containing nitrogen, in addition to carbon, oxygen, and hydrogen, which are found in the various vegetables and other articles of food. Unless an esculent contain nitrogen, it cannot be said to be nutritious. In treating of bread, I have before alluded to this fact at page 20. The quaternary compounds ALBUMEN, GLUTEN, FIBRINE, and CASEINE already described, are as much constituents of vegetables as of animals. To these must be added LEGUMINE, a substance not hitherto mentioned in this book. It abounds in many seeds used as vegetables, especially in such as are included in the natural family, *leguminosæ*, to which peas and beans belong.

Legumine is very soluble in cold water, and has a lustrous white appearance. On boiling a solution of it in water, it coagulates and falls in flakes like white of egg. The solidity of almonds, hazel-nuts, the kernels of stone-fruit, of peas, lentils, and beans, is due to its presence. Analysis indicates a very great similarity in composition between legumine, and the four other quaternary compounds separable from wheat-flour. The following shows the composition of them :—

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.
Legumine .	60·5	6·9	18·2	24·4
Fibrine . .	53·2	7·0	16·4	23·4
Albumen .	53·7	7·1	15·7	20·5
Caseine . .	53·5	7·1	16·0	23·4
Gluten . .	53·3	7·2	15·9	23·6

These nitrogenized substances, differing but little from one another, are those which are now recognised as distributed through the whole body of every vegetable. They all contain small quantities of phosphorus and sulphur; these are included in the above analyses, under the head of oxygen. Now, as the value of esculents must in some measure depend upon the presence of one or more of these compounds, I subjoin similar information on this head to what has been already given with reference to the quantity of water and starch found in them. The per centage value of grains, seeds, roots, and vegetables, is accordingly as follows:—

			Nutritive constituents.
Wheaten Flour	contains	from 10 to 35	per cent.
Dried Peas	contain	. . 29	,,
Kidney Beans	,,	from 24 to 28	,,
Green Peas	,,	. . . 24	,,
Lentils .	,,	. . . 22	,,
Haricots .	,,	. . . 22	,,
Maize .	,,	. . . 12	,,
Rice .	,,	. . . 7	,,

		Nutritive constituents.	
Yams	contain . .	3	per cent.
Mushrooms	" . .	2·9	"
Red Turnips	" . .	2·8	"
Sweet Potatoe	" . .	2·6	"
Cabbages .	" . .	2·5	"
Parsnips .	" . .	2·1	"
Beetroots .	" . .	2	"
Potatoes .	" . .	2	"
Kohlrabi .	" . .	1·5	"
Turnips .	" . .	1·5	"
Carrots .	" . .	1·5	"

The food of man, as regards vegetables, always contains nitrogen, in one or more of the five forms —albumen, gluten, fibrine, caseine, and legumine. The nutritive properties in food increase in the precise ratio of the presence of these substances; or, in other words, the value of different kinds of food is in proportion to the quantity of nitrogen or azote contained in them. The experiments of Magendie have shown that substances which contain no azote, such as sugar and starch, will not support life; and, on the other hand, it is ascertained that the quality of flour, for example, increases with the amount of gluten which it contains. We must therefore conclude, that the nutritious principles of plants and their products reside in their azotized principles. Not that these azotized principles

alone are sufficient for the nourishment of animal life, but it is found that every highly nitrogenized vegetable is generally accompanied by starch, gum, bone earth, and other matters which concur in nutrition.

Men and animals, then, find the several substances which make up their bodies ready formed in the substances they consume. A vegetable may be defined to be an organized being, which derives its food from gases and the soil; while an animal exists by incorporating into itself, from foreign sources, matter similar to that of which its own substance is composed. The constituents of meat are, as far as regards their nutritive properties, very similar to those of vegetables. Animal fibrine, albumen, and caseine, have their counterparts in vegetables: the history of animal albumen is that of vegetable albumen.

As food from without can only be made available by being first converted into BLOOD, and as it is the material from which all the secretions are derived, I shall proceed to a short description of it. In all vertebrated animals, the blood has a red colour, and a temperature above that of the medium in which the creature lives. In the ordinary state the blood has a slimy feel, a density of 1·053, and a decidedly alkaline reaction. To the naked eye, blood, like milk, appears a homogeneous fluid; but it is not *so in reality*. When examined by a good micro-

scope, it is seen to consist of a transparent, pale straw-coloured liquid, in which countless little red discs float. This may be readily seen when blood is left to itself, for it then coagulates, and separates into two distinct parts.

The SERUM of blood is the clear pale fluid part, and may be said to be an alkaline solution of albumen in salt water.

The CLOT OR CRASSAMENTUM is a mechanical mixture of fibrine and the colouring principle, swollen and distended with serum. In the blood we have an instance of fibrine in a soluble state. Its character may be best studied by agitating fresh-drawn blood with a bundle of twigs, when the fibrine attaches itself to the latter in form of long, white, elastic threads or fibres, which, under the microscope, appear to consist of small globules arranged in strings. It is quite tasteless, and insoluble in both hot and cold water. The colour of the clot is owing to a compound called HAEMATOSINE, which has many properties in common with albumen; but the globules of the blood, in which the colour naturally resides, are not composed of haematosine alone, but contain another albuminous compound, to which the name of GLOBULINE has been given.

Muscular tissue, muscular fibre, or meat, is composed chiefly of fibrine; mixed, however, in the ordinary state, with blood, membranes, nerves, fat,

&c. &c. A thin slice of lean flesh, washed in col water until perfectly white, affords an excellen example of fibrine in its insoluble form. Now, th basis of all meats, whether of fish, flesh, or fowl, i the same. If we extract finely-minced meat wit water, we obtain a reddish-coloured fluid, havin the taste peculiar to the blood of the different classe of animals. If we heat it, albumen coagulates at temperature of 150°, but the colour remains: if th heat, however, be continued, the fibrine, togethe with the colouring matters and cellular tissue, sepa rates, and a clear liquid is obtained. This *brot* will be found to be distinctly acid; that is to say, i will redden blue litmus paper. The acidity of th juice of flesh depends upon the presence of fre lactic and phosphoric acids. If one or other o these acids were removed, meat would be found t possess an alkaline reaction, for the blood has alway such; indeed, all the conditions of an electrical cur rent are present in the living organism. The blood vessels and lymphatics contain an alkaline fluid while the surrounding fluid (that of the flesh) i acid; the tissues of which the vessels are compose being permeable for one or other of these fluids It is, therefore, very probable, says Liebig, that a electrical current takes a share in the vital pro cesses, though very little is known about it.

The chemistry of flesh demonstrates that, accord *ing* to the duration of boiling, there takes place

more or less complete separation of its soluble constituents. If flesh employed as food is again to become flesh in the body, it should, as far as possible, contain all the original constituents of the raw meat. The *bouilli* without the *bouillon* is so much the less adapted for nutrition, as the quantity of water in which it has been boiled is greater; if meat be extracted with cold water, all the sapid and odorous principles are, together with the albumen, transferred to it. The smell and taste of roast meat arise from the soluble constituents of the juice, which have undergone a slight change under the influence of a higher temperature. Meat which has been rendered quite tasteless by boiling with water, acquires the taste and peculiarities of roasted flesh, when moistened and warmed with a cold water infusion of raw meat which has been evaporated till it has acquired a dark brown colour. From all the different kinds of flesh we obtain, by the aid of cold water, the whole of the albumen present in them, in the soluble form. Muscular fibre is everywhere surrounded by a liquid containing it, and the tenderness of meat is dependent upon the quantity present. In young animals it is great; in old ones it is small. Now, when meat is to be eaten, the albumen should be retained in it; for not only does it protect the fibrine from becoming hard, but it gives softness and delicacy. The influence of boiling water upon albumen is well known. The best

method of boiling meat intended to be eaten is to introduce it into boiling water; if the boiling be kept up for five minutes, and then so much cold water added as to reduce the temperature to 165°, and the whole kept at this temperature for some hours, all the conditions are united which give the flesh the quality best adapted for its use as food. When it is introduced into the boiling water, the albumen immediately coagulates from the surface inwards, and in this state forms a crust, which no longer permits the external water to penetrate into the interior of the mass of flesh. But the temperature is gradually transmitted to the interior, and there effects the conversion of the raw flesh into the state of boiled. The flesh retains its juiciness, and is quite as agreeable to the taste as it can be made by roasting. When the temperature of the interior of a piece of meat has not reached 144°, it presents a blood-coloured or underdone appearance.

The flesh of poultry is sooner done than meat, because it contains little blood, and therefore requires a lower temperature.

The use of lard in roasting is to prevent the extraction of the tasty constituents from the flesh by its juices, and the evaporation of the water, which causes hardening.

Now, although the introduction of the raw meat into boiling water is the best process for dressing it, it is the worst for obtaining soup. If the raw

meat be placed in cold water, and this brought very gradually to the boiling point, there occurs, from the first moment, an interchange between the juices of the flesh and the external water. The flesh loses, while the soup gains in sapid principles, and contains both lactic and phosphoric acids,—two most important constituents of the gastric juice.

The best method of preparing so-called beef tea, is to take 1 lb. of finely-chopped raw beef, to mix it with its own weight of cold water, and, after the lapse of about three minutes, to heat it slowly to boiling. It should be allowed to boil for two or three minutes, and should then be strained through a cloth; when an equal weight of the most delicious and strong beef tea, such as cannot be obtained by boiling for many hours, is at once obtained. When properly seasoned, it forms the very best soup that can be made.

It has long been customary to ascribe to the gelatinous matter dissolved during boiling, which gives to concentrated soup the property of forming a jelly, the chief properties or peculiarities of the soup; but there cannot, says Liebig, be a greater mistake. The simplest experiments prove that the amount of dissolved gelatine in well-prepared soup is so small, that it cannot come into calculation in explaining its properties. Gelatine (isinglass is pure, glue impure gelatine) is, in itself, quite tasteless, and consequently the taste of the soup cannot be derived

from it. Boiling water, when allowed to act for five hours on finely-chopped flesh, does not dissolve more than the fifth part of the matter soluble in cold water, even after the albumen has been separated by heating the cold infusion; and this fifth part, besides, does not consist of pure gelatine, but contains all the products dissolved out of the muscular fibre by long boiling.

It is equally customary to ascribe great strength to dark-coloured soups. A little burnt sugar (caramel) or burnt onion, will give depth of colour to the beef tea prepared after the above prescription.

Salted meat is deficient in nutritive and digestive properties, and should never be eaten by a dyspeptic person. In the process of salting flesh, the acids, much of the albumen, and other matters, are removed in the brine; and, as I have already pointed out that the juice of flesh is not very dissimilar to the gastric juice, it is obvious that its removal must render the meat less nutritious. It is probable, that if, before salting, the meat were plunged for three minutes into boiling water, it would not lose so much of its goodness. The practice of using salt meat at infirmaries is highly objectionable. The object—viz., that of making it keep in warm weather—may, I believe, be effected by plunging the fresh meat into slightly-salted boiling water, and re-heating till the water again boils.

The advantage of stewing over boiling depends on the fact, that in the former process all the soluble matter is retained in the sauce or juice, which is served with the meat.*

Taste being the best test of good cookery, it is obviously of the highest importance, in the process of cooking, to retain, as far as possible, the sapid principles of vegetables, as well as of meats. The practice of boiling meat or vegetables with large quantities of water, which is thrown away, and with it the whole, or nearly the whole, of the soluble matter, is clearly objectionable. The process of steaming is, in most cases, far preferable to boiling. Potatoes should always be boiled in their skins, for these keep in much that is valuable. Baked or roasted potatoes are, however, most wholesome.

We must not altogether overlook so important an element of dinner as cheese. It is a constituent of milk. When milk, freed from cream, is heated to 150°, or a little higher, and mixed with a little rennet, (an infusion of the stomach of the calf in water,) it coagulates, and gradually separates into a solid white matter, called *curd*, and a liquid portion, distinguished by the name of *whey*. Curd, when in a state of purity, is known by the name of *casein*. It has many properties in common with albumen, and, like it, may be obtained in two states; namely,

* See Liebig on Food, from which work the information on flesh here given is taken.

uncoagulated, when it is soluble, and coagulated, when it is insoluble in water. It is precipitated from its aqueous solution by acetic acid, which is not the case with albumen. It is coagulated by a boiling heat, but slowly: the scum we see on boiled milk is coagulated casein.

Coagulated casein, subjected to pressure for the purposes of freeing it from the whey, constitutes cheese. But if cheese consisted of nothing but casein, it would be hard, horny, and utterly tasteless. Good cheese is, however, always made from milk still retaining its cream or butter; and in Stilton, which is one of the richest cheeses, the milk is not only allowed to retain its natural quantity of cream, but an additional quantity is added. The fresh cheese being kept constantly cool and dry, undergoes a particular kind of putrefactive fermentation, very little understood, by which principles are generated which communicate a particular taste and odour.

Cheese, then, is a combination of a highly nitrogenized substance, casein, with butter. The difficult digestibility of cheese, as compared with meat, is no doubt owing to its composition. Not only is it insoluble in water, but it brings with it little that aids digestion. The use of cheese as a relish is no doubt an aid to digestion, for it acts as a solvent upon the food in the stomach.

In the first chapter of this book, I have alluded

to Liebig's division of all classes of food into such as keep up the animal heat, and such as restore the waste of the flesh. Every movement of the limbs, every glance of the eye, every thought that crosses the mind, is accompanied with the transformation of a certain amount of nitrogenous matter into a soluble form, to be ultimately expelled from the system. There ought to be a definite relation between the amount of nitrogenous or nutritive matter taken into the system, and that of the starchy or calorifiant (heat-producing); hence a right diet must consist of that in which the nutritive matter is properly proportioned to the calorifiant matter. To preserve the human system in a healthy condition, the quantity of food taken at meals should be in proportion to age and the amount of exercise taken. A person who takes much active exercise in the open air, or whose work is such as to give vigorous employment to the muscles, will be able to eat double the quantity that would be good for one who leads a sedentary life. The state of the weather, too, has much to do with the quantity, for the colder it is, the more food is necessary. The Esquimaux will devour as much as twelve pounds of raw whale's blubber in a day; whilst those who live in hot climates eat a very spare diet. It should, therefore, be borne in mind, that we are not in all cases to eat a certain quantity of food merely from *custom*. *It is further* very important to avoid over-

drinking at meals; large draughts of water or beer chill and disorder the stomach, rendering it unfit to perform the functions of digestion. It should be remembered that the quenching of thirst does not depend upon the quantity of liquid imbibed; and that, in general, less than half-a-pint of fluid, whether it be in the form of water, beer, coffee, tea, or cocoa, drunk in small quantities at a time, will suffice at each meal.

CHAPTER VI.

THE CHEMISTRY OF GLASS, CHINA, AND EARTHENWARE.

Of the many beautiful discoveries made by the ingenuity of man, none is so beautiful, so perfect, in fact so nearly approaching to the production of nature, as GLASS. When, or by whom, the art of glass-making was discovered is unknown; but that it was practised in very ancient times is certain. A kiln of bricks could scarcely be burnt, or a batch of pottery made, but some of the bricks and the ware would be at least superficially turned to glass. From many writings of the ancients, it is certain that glass was well known, but it was reserved until comparatively modern times to manufacture, with certainty, a perfectly colourless and transparent article.

Glass, as is very generally known, is an artificial product. As a natural product, resembling glass in many of its best properties, we recognise quartz, or rock-crystal; and this mineral, often perfectly transparent and colourless, is so hard as to give sparks

when struck with a steel, and is infusible in fire. The fine crystals are cut into ornaments, and frequently used as a substitute for glass in spectacles; they are then called pebbles, and possess one advantage over glass, that they are not easily scratched. *Brown* and *yellow rock-crystal* are found in great beauty in the mountain of Cairn Gorm, in Scotland. That beautiful gem called *Opal*, is a specimen of pure rock crystal, combined chemically with water. In fact, all the varieties of beautiful stones, known and valued by young and old, under the various names *Agate*, *Blood-stone*, *Carnelian*, *Flint*, *Amethyst*, and *Onyx*, are but varieties of melted *sand*, coloured by metallic oxides; they are glass, of nature's manufacture.

The technical names for rock-crystal and the various species of sand, are SILEX, SILICA, and SILICIC ACID. The chemistry of silex is briefly this. It is not an element, but a compound of the element silicon, which is never found native, with oxygen. The most finely-powdered silex feels harsh and gritty between the teeth, is utterly tasteless, and insoluble in water. It may seem at first sight strange to call such a substance silicic acid, as it appears to be devoid of all acid properties. But it may be here observed that a chemist, by the word acid, "does not of necessity mean a substance possessed of an acid taste, and capable of reddening blue *litmus* paper." No substance insoluble in water

can be possessed of taste. An acid is a combination of an element, usually with Oxygen or Hydrogen, possessed sometimes, though not necessarily, of a sour taste, but always of the power, under proper arrangements, of forming a salt by union with a metallic oxide or base. Silica is a very powerful acid, although its properties as such are only displayed under the action of considerable heat. At high temperatures it is one of the most powerful acids with which chemists are acquainted. It has been observed above, that silica is naturally insoluble in water; nevertheless, it may be rendered soluble, by several of the great and potent agents which are ever silently in operation in nature. For the supply of very many plants, into the structure of which it enters, and in which it seems to play the same part as the bones do in animals, silica must become soluble in the soil, or else the delicate stomata or mouths of the rootlets of plants would refuse admission to it. And that it does so become soluble, is certain. It is even found in spring and mineral waters. In the boiling Geysers of Iceland, it is contained in such quantities as to be deposited by them in porous masses, not very unlike stalactites.

Finally, silica is known to exist in two distinct forms, the soluble, and insoluble. The soluble passes into the insoluble, as soon as it has once been separated from its solvent, and dried.

But rock-crystal is not glass. Glass is a fused

mixture of combinations of silica, with basic oxides; of silicates or salts of silica. As it would be impossible to understand the chemistry of glass, without first considering the nature of the substances with which the silica combines in its formation, I will at once proceed to explain them.

Wood-ash, pot-ash, and pearl-ash, are the names given to the more or less pure carbonate of potash of commerce. This salt, which consists of a combination of carbonic acid with potash, is exclusively supplied by the combustion of wood and other vegetable substances; its production on a large scale is therefore necessarily confined to those countries in which timber abounds.

Pure carbonate of potash is a white granular salt, soluble in its own weight of water, fusible at a red heat, and possessing great attraction for water. The potash of the carbonate is a very powerful basic oxide, combining readily with acids, and forming salts. It is very acrid and corrosive, and is hence commonly called caustic potash. At a white heat it is decomposed by charcoal, and thus the metal *Potassium* may be separated from the oxygen, with which in *Potash* it is combined. Potassium is a blueish-white metal of great lustre, having so strong an attraction for oxygen, that it can neither be kept in air nor water. It is preserved by immersion in naphtha, a liquid compound of carbon and hydrogen.

When one part of silica, and two-and-a-half parts of carbonate of potash are fused together, the carbonic acid is expelled, and a silicate of potash is formed, which is soluble in water, and known by the name of *soluble glass*. A concentrated solution of this in water, mixed with chalk or fine china-clay, is sometimes used as a paint, to render wood, paper-hangings, and other like articles incombustible.

When pearl-ash, and a great excess of silex are melted together, a nearly insoluble silicate or species of *glass* is obtained.

But one of the constituents of glass is soda. In the same manner as carbonate of potash is obtained by the combustion of land-plants, so in former times was all the carbonate of soda of commerce obtained from the incineration of sea-weeds. Barilla and kelp were the names of the rough carbonate known in the markets, and twenty-four tons of sea-weed were required for the production of one ton of kelp. A very pure carbonate of soda, which, on account of its cheapness, has been made to supersede in many of the arts the far more expensive carbonate of potash, is now manufactured on an immense scale in England, by the decomposition of sulphate of soda (glauber salt).

The carbonate of soda of commerce is a salt, very large transparent crystals of which may be frequently seen in the windows of oil-shops. It contains a large per-centage of water, a portion of *which it exhibits* a tendency to lose, and thus we

often see the transparent crystals covered with a white powder of anhydrous carbonate of soda. When heated, it melts in its water of crystallization, and, if the heat be continued, gives off all its water. The dry carbonate thus obtained is a white powder, soluble in two parts of water, to which it communicates a strong, disagreeable, caustic taste. The soda of the carbonate is a very strong basic oxide or base, only second to potash in its affinities or powers of attraction. At a white heat, caustic soda may likewise be decomposed by charcoal, and the metal *Sodium* obtained. It is silver white, very soft, and tarnishes immediately on exposure to air. Sodium, like Potassium, must be kept under rock-oil.

The compounds of silica with soda are so similar to those of potash, that it is needless further to describe them. Suffice it to say, that, no matter how pure the materials employed, the glass resulting from the use of soda is always possessed of a greenish hue.

Lime is likewise used in the preparation of glass. Carbonate of lime or mountain-limestone, forms, as is well known, whole ranges of hills in many parts of the world. Chalk, calcareous spar, and marble, are other names for varieties of carbonate of lime. It is almost insoluble in pure water, requiring as much as 10,601 parts to dissolve one of pure carbonate of lime. When mountain-limestone is heated intensely in the lime-kiln, it loses its carbonic

acid, and becomes oxide of calcium, lime, quick-lime, or caustic lime, these being the various names by which the product is known. It is a powerful base, very caustic, requiring 750 parts of water for solution, to which it shows great affinity. In fact, when a few drops of water are poured upon a piece of quick-lime, it falls down into a fine white powder, emitting at the same time a great amount of heat. This operation of *slaking* lime may be seen any day, wherever building operations are carried on; the heat generated in the process is frequently made use of by the workmen for the purpose of warming their tea or coffee, and it has been made use of for cooking meat. The emission of heat is caused by the union of the water with the lime; the former becoming solid, gives off the heat necessary for retaining it in a liquid form.

Lime, like potash and soda, is the oxide of a metal called *Calcium.*

Oxide of Lead, which may be prepared by exposing the grey powder which forms on melted lead to the further action of heat and air, until it acquires a uniform yellow colour, is a most important agent in the manufacture of glass. It forms very fusible salts with silex, and as these are beautifully clear and colourless, its value for the purpose of glass-making may be readily conceived.

By further exposure of this oxide of lead to the action of heat and air, at a high temperature, though

below its melting point, it attracts a further quantity of oxygen, and acquires gradually a fine red colour. *Minium* or *Red lead* is preferred in glass-making to the ordinary oxide or litharge, because the excess of oxygen over that of litharge, although given off at a red-heat, has the power of oxidizing and removing any organic impurities which may have become mixed with the various ingredients, and which otherwise would impair the brilliancy of the glass.

Glass, the manufacture of which will after this preparation not be difficult to understand, is altogether destitute of crystalline structure. It is, essentially a compound of silica with potash or soda, lime, and oxide of lead. The silica employed must be of greater or less quantity, according to the purpose designed by the manufacturer. Fine white sand is usually employed; sometimes ground flints, or the white pebbles so abundant in many rivers. When the purity of the glass is of importance, carbonate of potash or soda is used; while for common glass, wood-ash, barilla, and kelp are sufficiently pure. The proportions of the raw materials will vary much, usually about half the weight of the silica being the proper amount. During the process of fusion, the carbonic acid of the carbonates escapes in bubbles, and the glass is ready for use as soon as the melted mass is free from the bubbles of escaping gas. A glass composed entirely of silica and potash, or soda, requires a very high tempera-

ture for perfect fusion; and this is the chief reason for the employment of litharge or of red lead. The fusibility is much increased, and the compound is not only more tenacious and workable when hot, but bears changes of temperature better. London flint-glass, so celebrated for its brilliant transparency, is prepared with oxide of lead; but, in consequence of its softness, it is very liable to become scratched. The composition of flint-glass, according to Faraday, is as follows :—

Silica	51·93
Potash	13·77
Oxides of lead . . .	33·28
Impurities and loss . .	1·02
	100·00

The mixture of materials for glass is technically termed *fret;* their fusion is conducted in large crucibles, or glass-pots, made of the most refractory fire-clay, which in the case of lead glass, are covered by a dome at the top, and have an opening at the side at which the materials are introduced, and the melted glass withdrawn. At a full-red, which is the working heat, the glass has a very tenacious consistency, and as it scarcely adheres to polished metal, it is easily worked with iron tools. The circular tables of *crown-glass* are made in the following manner: the workman having collected the proper quantity of glass, in the soft pasty state, at

the end of his blowpipe, commences blowing, by which the lump is expanded into a kind of flask. The latter is fastened at bottom to an iron rod or puntil, by means of a little fresh glass obtained from the glass-pot, and the blowpipe is removed from the neck of the flask by the application of cold iron. The flask is suddenly made to assume the form of a flat disc or plate, by the centrifugal force induced by the rapid wheel-like movement given to the puntil. Crown-glass or window-glass is made of soda, sand, and about six per cent of lime. (Fownes.)

Plate-glass is cast upon a flat metal table, and polished by machinery.

One of the most important parts of the glass-making process is that of *annealing*. This consists in arrangements for allowing the glass to cool very slowly, else it is apt to be brittle and to *fly*, as it is called. Tumblers and wine-glasses, when first bought, are treated by careful house-wives in the following manner. They are put into cold water, upon which a little hay is placed, and this is carefully and slowly raised to the boiling point. If the water is then allowed to cool slowly, glasses thus treated will stand any sudden change of temperature. The use of hay or such materials is to prevent any sudden contact of cold: in fact to allow the cooling of the water to proceed evenly.

It has been already stated, that the use of potash

secures a clear, and in fact the only perfectly colourless glass. The very beautiful Bohemian glass consists, according to Mitscherlich, of—

Silica	60·0
Potash	25·0
Lime	12·5
Manganese, alumina and loss . .	2·5
	100·0

The various colours are communicated to glass by metallic oxides. Oxide of manganese produces an amethyst colour; oxide of cobalt, a blue; oxide of gold, a purple; sub-oxide of copper, a ruby-red; oxide of copper, a green; oxide of silver, a yellow; oxide of chrome, a green; oxide of iron, a bottle-green, &c. In glass-painting the oxides are applied to the surface of the glass, which is then re-heated until fusion of the colouring-matter in the glass-surface takes place. An opaque white appearance is given to the enamel of watch-faces, by oxide of tin.

CHINA, STONEWARE, AND EARTHENWARE.

The art of making Pottery is intimately connected with the subject of glass. There are few branches of industry of greater antiquity than that exercised by the potter. The plastic qualities of clay, and its hardening when exposed to heat,

are properties which suggested in very early times its application to the making of utensils for the manifold purposes of daily life.

The slates and tiles with which our houses are roofed, the bricks of which they are built, the china of which our cups and saucers, the earthenware of which our plates are made, are nothing more than varieties, more or less pure, of the clays and marls so abundant in various spots of the earth, as to have induced men to build their cities upon them. What then is clay?

Pure clay is a beautifully white substance composed of silica and alumina. It is a true silicate. *Alumina* (contained in alum) or *argil*, as it is sometimes called, is the *oxide* of the metal *Aluminum*. Native alumina constitutes the *sapphire*. The *oriental ruby* and *topaz* are red and yellow varieties of this earth. *Corundum* and *emery* are minerals consisting of alumina, with less than two per cent. of oxide of iron and silica. The crystalline varieties of alumina, are only second to the diamond, with respect to hardness.

Alumina, as prepared in the chemist's laboratory, is a white, tasteless, coherent mass, possessing great mechanical attraction for water, which it greedily sucks up. Unlike potash, soda, and lime, it is a very weak base. Infusible in all furnaces, it yet yields to the heat of the oxy-hydrogen blowpipe.

Alumina must not be confounded with clay, a very

common mistake. The only clay suitable for the manufacture of china, is the so-called china-clay, or kaolin; and even this substance is the result of the decomposition of more compound silicates than clay. The ancient unstratified rocks, but more especially granite, and porphyry, contain largely a mineral, felspar, which, under certain circumstances, and in the course of time, decomposes, loses its original hardness, and becomes a mass of soft, white, earthy matter, resembling wet slaked lime. The exact nature of the change of felspar into clay is not certainly known; the felspar, a definite combination of silicate of alumina with silicate of potash, acted upon by the carbonic acid of air, and by rain, parts with the silica and potash, and becomes converted into china-clay.

In the manufacture of porcelain, great skill is required in the selection of materials. No oxide of iron must be present in the clay to mar the perfect whiteness of the china. As the clay has to undergo intense heat, and that long-continued, no easily fusible materials must be left in, or added to it, beyond what is necessary to the production of a semi-translucent glassy texture, and to the prevention of too great shrinking. To effect all these objects, proper proportions of crushed flints and of felspar are intimately mixed with the clay, and great care is taken that the materials, when mixed with the proper quantity of water, form a uniform

pasty mass, free from grit. China-ware is formed from it, either on the potter's wheel, or in moulds of plaster. These are then air-dried in a warm room, and being enclosed in baked clay cases, somewhat resembling band-boxes, and called seggars, are ranged in the furnace. This is a structure, somewhat resembling a kiln, made of bricks, having several fire-places, and surrounded by a lofty dome. The cases are so closely packed, as only to leave space for the full play of the flame. Here the ware is kept red-hot for many hours, and the fires are allowed to die out before the seggars are removed. Biscuit-ware is thus produced. This is afterwards glazed, by dipping it momentarily into a tub containing a mixture of certain proportions of felspar, or of gypsum, silica, and a little porcelain-clay, diffused through water to a creamy consistency. The ware absorbs the water, and the powder remains evenly spread over its surface. It is once more dried, and then exposed to a temperature sufficiently high to melt the glaze.

The colours employed in painting china are the same metallic oxides used for painting or staining glass. The colours are mixed with oil of turpentine or of spike lavender, and applied with a camel-hair brush. When several colours are used, those that bear a high temperature are first laid on, and burnt *in*, before those which can stand only a lower heat are applied. The gilding is generally done by

applying finely-divided gold, mixed up with gum-water and borax (a salt of soda and boracic acid). Upon the application of heat, the gum burns off, and the borax, vitrifying upon the surface, causes the gold to adhere firmly. It is afterwards burnished.

STONEWARE

Is a coarse kind of porcelain, containing both oxide of iron, and lime, to which it owes its colour, and its partial fusibility. The glazing is effected by throwing common salt into the heated furnace. This is volatilized, and decomposed by the joint agency of the silica of the ware, and of the vapour of water always present. Hydrochloric acid and soda are produced, the latter forming a silicate, which fuses over the surface of the ware, and gives a thin, but excellent glaze. (Fownes.)

EARTHENWARE.

The pottery, commonly called *Staffordshire ware*, is made from a commoner white clay than porcelain-clay, mixed with ground flints in considerable quantities. The mode of manufacture is the same as in the case of china, but the glaze is different. It consists of a mixture of about sixty parts of litharge, ten of clay, and twenty of ground flint, diffused in water to a

creamy consistency. This glaze is very fusible. The painting on this ware is usually blue, in consequence of the cheapness, and the facility of application of the oxide of cobalt. The pattern is first printed off upon paper, which is applied to the plate or other article before glazing. When the ink is dry, the paper is washed off, and the glazing completed.

The whitish opaque glaze, which we see on the coarser kinds of earthenware, contains the oxides of lead and tin. They are unfit for culinary purposes.

CHAPTER VII.

ON THE CHEMISTRY OF SOAP.

In a chemical point of view, the manufacture of soap is extremely interesting, and forming as it does one of the most important articles of domestic use, a short account of its composition, and the process of its manufacture cannot be omitted in a work professing to illustrate household chemistry.

The Latin word Sapo, and the Greek Σάπων, signifying soap, are undoubtedly derived from the German; for we find the corresponding word *Sepe* is still used in the Low German dialect. Pliny, who makes the earliest mention of soap, declares it to be an invention of the Gauls, though he prefers the German to the Gallic soap. Both hard and soft soap were in use among the Germans. Pliny relates that it was made from tallow and ashes, and that it was employed both as a medicine, and for washing clothes.

In the remotest periods, it appears certain that clothes were cleansed by being simply rubbed or

stamped upon in water, without the addition of any extraneous substance. In the sixth book of Homer's Odyssey, we read that Nansicaa and her attendant washed their clothes by treading upon them with their feet in pits, which they had filled with water.

At a later period mention is made of a lye of ashes being employed for washing, and that with it oil and wine-jars were cleansed; and there can be little doubt that a solution of wood-ashes, or of impure carbonate of soda was used for the purpose.

The ancients appear also to have employed at least one description of plant with a saponaceous juice, as a substitute for soap, but the precise plants used cannot be ascertained; and it is also certain that they made use of fuller's-earth, much oftener than is done at present. *(Beckmann's History of Inventions.)*

The chief soaps manufactured in this country are:—white soap, yellow soap, mottled soap, brown soap, soft soap, and silicated soap.

The subject of saponification will not be difficult to understand, the reader having had some preparation in the numerous allusions to the subject. At pages 15, 61, and 62, somewhat of the nature of oils and fats has been described; and although the little information already given must be somewhat expanded, no new terms will be required in the explanation of the subject.

Our knowledge upon the subject of oils and fats

is very considerable; no branch of chemistry having been studied with more decided success. These substances form a natural group, in which the animal fats agree closely with the vegetable. All oily substances may be divided into *fixed* and *volatile.* When dropped upon paper, both kinds produce a greasy stain, which *disappears* when heated, in the case of a volatile oil, but *remains* when produced by a fixed oil. Of course, then, the volatile oils are alone odorous; and wherever a fixed oil is perceived to be possessed of smell, we may be sure of the presence in it of a volatile oil. This is well illustrated by the case of butter. The margarine and oleine have no smell, but the butyrine, amounting to three per cent. (see page 15), gives both smell and taste.

A very important property of oils is that of drying or not drying by exposure to air. The terms *drying* and *non-drying* can only be applied to fixed oils, as a volatile oil (for example attar of roses) would fly off in vapour. All oils are altered by exposure to air. In the case of the oils used in making paints (linseed, rape, walnut, and poppy), they absorb oxygen, and become hard and resinous. All animal fats and oils, as well as olive and palm oil, likewise attract oxygen, which makes them acid and rancid, but never dries them.

As in the case of the metals, so in oils, we find a great difference as regards hardness. Between

the very fluid olive oil and hard mutton suet, there lie the greatest varieties of consistency. The difference, as I have already had occasion to explain, depends upon the proportion in which the great fatty principles are mingled. It is as easy to mingle them in any proportions, as to separate them. Thus, olive oil, exposed to a temperature a little above the freezing point, deposits a solid fat, and separates into two distinct substances: *oleine*, a liquid, and *margarine*, a solid substance of pearly lustre, separable by simple pressure from the oleine. Again, if suet be pressed between folds of blotting paper, whilst the paper will be found stained with oleine, the suet itself will have become much harder, less fusible, and less tenacious. It consists now of margarine and *stearine*, the latter a white and lustrous substance.

In the process of saponification, the acids of the three substances oleine, margarine, and stearine, combine with the potash or soda; the essentials in this process forming soap, while the glycerine is set at liberty. Soap is therefore a true salt, the acid being oleic, margaric, or stearic, the base potash or soda. When, for example, mutton fat, or tallow, is boiled with caustic potash or soda for a time, it gradually dissolves, forming, with the alkali, a transparent viscid mass, soluble in water.

At page 110, I have spoken of carbonate of potash *as being* used in the manufacture of glass. Caustic

potash is prepared from it in the following manner. One pound of carbonate of potash is dissolved in ten pounds of boiling water in a clean iron vessel. Into it is stirred, by degrees, three-quarters of a pound of quick-lime, previously slaked. After a few minutes fierce boiling, it will be found, on examination, that the carbonate of potash has parted with its carbonic acid to the lime, which has become converted into carbonate of lime, or chalk, and a solution of caustic potash in water has been obtained. It is removed from the fire, and will be found, after the lapse of a very short time, to consist of a clear solution of potash, which should be carefully poured off from the heavy sandy precipitate of chalk, and excess of lime. The solution possesses, in the highest degree, the properties termed alkaline. It dissolves the skin, when subjected to its action. It restores the blue colour to reddened litmus paper; combines with, and neutralizes the most powerful acids, and is possessed of a most peculiarly nauseous and biting taste. It unites with fats and oils to form soap, as explained; hence the term soap-lye given to the solution of caustic potash.

Caustic soda is, however, more generally used in the manufacture of soap than potash. At page 111, I have indicated the source from whence all carbonate of soda is now obtained. It may be as well to add, that the Glauber salt, or sulphate of soda, which has been spoken of, is made entirely

from common sea-salt. The description of the process employed in the manufacture of caustic potash applies exactly to that of soda, premising only that dry carbonate of soda is to be employed.

Soaps are either hard or soft; the former being compounds of fats or oils with soda,—the latter with potash. Soft soap is made with potash and drying oils, either alone, or mixed with tallow, and other coarse and fatty matters. The best hard white soap is made from olive oil and soda. The oil is mixed with the lye, and boiled in an iron pot, until the fat is completely saponified, which may be known by its becoming clear and transparent. The boiling is continued until the soap begins to separate, and this result is accelerated by the addition of common salt. White soap is sometimes composed of tallow and soda. Yellow soap is made of tallow, resin, and soda, a little palm-oil being occasionally added. The peculiar appearance of mottled soap, formed of tallow, kitchen-stuff, and soda, is communicated, by dispersing the lees through it towards the end of the operation. Brown soap is made from palm oil, resin, and soda.

The so-called *silicated* soap, of which large quantities are now manufactured, is made by combining silicate of soda, or soluble glass, with hard soap, in the hot pasty state; from 10 to 30 per cent. may be introduced. Such soap possesses, according to Dr. Ure, very powerful detergent qualities,

but it is apt to feel hard, and somewhat gritty in use. The silicate of soda, with excess of soda, is obtained by boiling ground flints in a strong caustic lye.

Many substances are used to adulterate soap, such as clay, potato-starch, &c., for which improvements, as they are termed, numerous patents have been granted (*Beckmann*).

Soap is soluble in pure soft water, without decomposition. But when waters contain gypsum, which, with other saline constituents, make water hard, then it is decomposed. At first the water becomes full of flakes, and the cleansing properties of the soap are not brought into play until the action of the acids of the salts present in the water upon the potash or soda in the soap has ceased. Thus, when gypsum, or sulphate of lime in solution, is brought into contact with soap, the potash or soda combines with the sulphuric acid, and an insoluble lime-soap separates in white flakes from the water. This fact explains the importance of soft water for domestic purposes, and indicates the cause of the great waste of soap by the use of hard water.

The cleansing property of soap is due to the fact, that the greater part of the dirt upon our linen, or our clothes, consists of oily perspiration, grease, or of dust which that grease fixes, and which either cannot be removed at all, or but very imperfectly, by washing in water alone. But if soap be used,

its alkaline character displays itself; the grease unites with the potash or soda, forms, in fact, a soap, and may then be removed by water.

Fuller's-earth, a white clay, acts, partly by scouring, partly by absorbing the greasy dirt.

If cleanliness be, as the proverb hath it, next to godliness, the manufacture of soap must needs be an important one; so much at any rate does the comfort of a community depend upon this useful article, that Liebig has considered the consumption of soap to afford a good test of the comparative civilization of nations. In this country it is manufactured on a very large scale; and great quantities are annually exported to foreign countries. Owing to its universal use it has been considered a good means of raising a revenue; and since the reign of Queen Anne it has been more or less heavily taxed. There is no doubt that taxation acts as a considerable check upon the free use of soap, and at the present time, when so much stress is laid upon all matters affecting the sanitary condition of the population, the importance of the unrestricted use of soap is generally felt. The quantity consumed is known, in spite of restrictions, to be very large, and in 1848 amounted to nearly 190,000,000 lbs.

CHAPTER VIII.

THE CHEMISTRY OF HOUSEHOLD METALS.

The grand store-house of the metals is the earth, which, however, as a rule, does not contain them in the form in which we are familiar with them, known as *native,* but in combination either with one another, with oxygen, or with sulphur. When combined with each other they are termed *alloys;* in combination with oxygen, *oxides;* and with sulphur, *sulphurets.*

The number of metals known to chemists is forty-six, but those with which we should endeavour to familiarise ourselves, are only eight in number——viz., *gold, silver, quicksilver, zinc, lead, tin, copper,* and *iron.* All of these are distinguished by certain physical properties. Their most striking character is what is commonly termed *metallic lustre.* The thinnest leaves of metals intercept the passage of light so completely, that this property is, no doubt, connected with, if not dependent upon, the degree *of opacity* which all present.

The differences of *specific gravity* in the metals are most remarkable. Those, for example, which are contained in the form of oxides in soft and hard soap—viz., potassium and sodium, are lighter than water, whilst gold is upwards of nineteen times as heavy.

In point of *colour*, we have, fortunately, in the household metals all the varieties which the metals present. Copper is red and gold yellow, but the rest present a great degree of uniformity, ranging between the brilliant whiteness of silver and the dull grey tint of lead.

In *fusibility*, or the degree of heat at which they melt, metals differ most widely. From quicksilver, which is liquid at all ordinary temperatures, to pure iron, which requires the heat of a blast furnace; and from this again to metals of the nature of platinum, which is infusible in furnaces,—a variation of several thousand degrees of heat is to be found. Some metals soften and assume a pasty state before they become liquid. This is the case with iron, which thus admits of being welded, or united together without solder. Thus a bundle of small pieces of iron, when heated to redness, may be joined together into one solid lump by a few powerful strokes of the hammer.

There can be little doubt but that the metals are *capable of* assuming all the three forms of matter. *Quicksilver* boils and volatilises at a temperature

much below red-heat, and becomes a solid at 39° below the zero of Fahrenheit. Were a sufficient amount of heat obtainable, even those metals which now appear exceptions would, doubtless, be found to follow the same rule.

Some metals possess the property of *malleability*, or the power of extension under the hammer, to an amazing extent. Of this, gold leaf is a remarkable example. Zinc stands in the middle, between the malleable and brittle metals. Arsenic is entirely destitute of malleability; instead of being flattened out by a stroke of the hammer, it would fly into pieces. Now, *ductility* differs from malleability, as it involves the principle of tenacity, or the power of resisting force. The art of wire-drawing depends upon this ductile property of metals.

Lastly, it may be said that most metals are capable of assuming regular forms, or of *crystallization*.

1. Gold. Latin, Aurum. Symbol, Au. Sp. gr. 19·26, Water being as 1·00.

Although traces of this noble metal are to be met with in every country of Europe, yet the labour of obtaining it is so great, as to render it the most expensive of all metals. It is always met with in the metallic state, usually associated with quartz and other substances, and sometimes beautifully crystallised. It abounds mostly in the countries which lie

between the tropics; in Africa, towards the Equator, in Peru, Brazil, and Mexico, it is found in small grains, mixed with the sand of rivers. For the purpose of separation, a quantity of the auriferous sand is taken and washed with water, when the gold, by its own weight, sinks to the bottom; and thus, by repeated cleansing, the gold-dust of commerce is obtained. When gold is found embedded in stone, it is stamped to powder, and shaken in an apparatus with mercury and water; a combination of the two metals, called an *amalgam*, is formed, after which, the quicksilver is separated from the gold by the process of distillation. In California, the gold is of great purity, and has been found in very large lumps.

Gold is a soft metal, of a beautiful yellow colour. Its unchangeableness on exposure to air, its beautiful colour, its splendid metallic lustre, and its high specific gravity, have caused it to be regarded as the king of metals. The alchemists represented it by the circle ☉, which is also the emblem of perfection, and called it Sol, or the sun. It surpasses all metals in malleability; this is well illustrated by the fact that thirty ordinary-sized gilt buttons are covered by a single grain of gold. It is also so ductile that one grain may be drawn into a wire 500 feet in length. The process of wire-drawing is very simple; it consists in drawing rods of metal through a succession of trumpet-shaped holes in a steel-plate, each being

a little smaller than its predecessor, until the requisite degree of fineness is obtained. As the metal, in this process, is liable to become hard and to break, the metal intended for wire is previously made to undergo the operation of *annealing*, which is accomplished by heating it to redness and allowing it to cool slowly, by which means its toughness is greatly increased.

Gold, in consequence of its softness, is not very durable: for coin, and for elaborate articles of jewellery, it is therefore always alloyed with silver or copper. All the gold at present coined is alloyed only with copper; previous to the year 1826, the alloy likewise contained silver,—hence the paler colour of that coinage. Our English sovereigns and half-sovereigns contain one-twelfth of their weight of copper.

Gold-leaf is made by rolling out plates of pure gold as thin as possible, and then beating them between folds of membrane with a heavy hammer, until the requisite degree of tenuity has been obtained. Its thickness amounts to only $\frac{1}{282000}$ of an inch. The gold-leaf is made to adhere to the wood of picture-frames, or other surfaces, by means of size or varnish.

The modern process of electro-gilding is effected by dipping the articles into a solution of gold (obtained by dissolving oxide of gold in a watery solution of

so-called cyanide of potassium), into which the poles of a battery are introduced.

2. Silver. Latin, Argentum. Symbol, Ag. Sp. gr. 10·5.

As gold was compared by the alchemists to the sun, silver became the emblem of the pale "silvery" moon, under the name of Luna, or Diana; symbol, ☽. It is found in the native state, and in combination with sulphur, as sulphuret of silver. Among the principal silver-mines may be mentioned those of Peru and Mexico. The mines of Saxony, Bohemia, and Suabia, and those of Kongsberg in Norway, are the richest in Europe.

The chief part of the silver of commerce is obtained by the process of amalgamation, founded on the easy solubility of silver and other metals in quicksilver. The fluid amalgam, which is easily separated from the mud of the ore by subsidence and washing, is strained through a strong linen cloth, and the solid portion exposed to heat in an arrangement by which the mercury is volatilized and collected separate from the silver, which is left behind in a more or less pure state, according to the nature of the ore.

A very large quantity of silver is obtained from some native ores of lead. For the purpose of *obtaining* the silver from this description of ore,

the lead is re-melted, and allowed slowly to cool. The portion which first crystallizes is nearly pure lead; the alloy of silver, being more fusible than lead itself, is drained off, and found to contain all the silver. The further process depends upon the fact that lead oxydizes easily, whilst silver has no such tendency. And in this lies the difference between *noble* and *base* metals. The former not only do not easily oxydize, but, on application of heat, their oxides part with oxygen, and are reduced to the metallic state. The opposite is the case with the latter, and they easily oxydize, tarnish, or rust. When, therefore, this silver-lead is exposed to a red-heat on the shallow hearth of a furnace, while a stream of air is allowed to play upon its surface, the lead rapidly oxydizes, and the oxide is constantly swept away by the blast. When the chief part of the lead has been thus removed, the residue is placed in a shallow dish made of bone-ashes, and again heated. The last of the lead is now removed; it becomes oxydized, and sinks into the bone-ash, while the pure silver remains behind, exhibiting all its native brilliancy.

Pure silver is the whitest of all metals; it has considerable brilliancy, aud takes a high polish. It is harder than gold, and melts at a bright red-heat. It resists the action of air and water. The tarnishing of silver is due to sulphur, and not to oxygen. It is highly malleable and ductile, and may be extended

into leaves not exceeding $\frac{1}{10000}$ of an inch in thickness, and drawn into wire far finer than human hair.

Silver plate and coin are formed of an alloy of silver with copper. By the addition of a small quantity of copper, silver becomes harder, while its whiteness is scarcely impaired. The standard silver of England contains, in 12 parts, $11\frac{1}{10}$ of pure silver, and $\frac{9}{10}$ of copper. When such silver is heated to redness in the air, it blackens, from the formation of black oxide of copper; if this be removed by immersion in hot dilute sulphuric acid, a film of pure silver, called *blanched* or *dead silver*, remains. The blanks for coins are treated thus before they are struck, whence the *whiteness* of new coin.

The better kind of *plating* is performed by the application of a plate of silver to the surface of the copper, which is afterwards beaten or drawn out. *Electro-plating* is now very generally employed. The beauty of the metal, and its freedom from injury by the air, render it well adapted for ordinary purposes, and it is now frequently used for the inside of saucepans; it should, however, be kept clean, all contact with acids being avoided.

Whilst on the subject of silver, it may be mentioned that one of its salts is a component part of *marking-ink*. Silver is easily soluble in nitric acid, and forms a perfectly clear and colourless *solution*. By exposure to light, it is again partially

reduced to the metallic state, and minute particles of silver, in form of a fine black powder, separate. It is very caustic, and easily destroys both skin and flesh when concentrated. Indeed, such a solution of nitrate of silver, evaporated to dryness, fused, and cast in small cylinders, forms the lunar caustic of medicine. Indelible or marking ink is but a solution of lunar caustic, or nitrate of silver, in water, blackened by Indian ink, and thickened by gum arabic. Nitrate of silver is likewise an ingredient of hair-dyes.

3. QUICKSILVER or MERCURY. Latin, HYDRARGYRUM. Symbol Hg. Specific gravity 13·56.

This metal is not only of great importance in medicine and in the arts, but, is the only example we possess, of one, fluid at the temperature of most climates. Its silver-white colour and its fluid property gave rise to its name; the word Hydrargyrum being derived from the Greek ὑδωρ, *water*, and ἀργυρος, silver.

It has been known from very remote ages. Combined chemically with sulphur, as *sulphuret of mercury*, *cinnabar*, or *vermilion*, it is found in considerable quantities in Almaden, New Castile, and Idria, in Carniola; and is occasionally met with in the metallic state. The process of obtaining this metal from its ordinary ore, the sulphuret, is dependent

upon the removal of its sulphur. One method is to heat it with a metal which has a strong affinity or attraction for the sulphur with which the quicksilver is combined. Thus, if cinnabar be heated with iron-filings in an iron retort, the mercury will distil over, and the iron combined with the sulphur, remain as sulphuret of iron in the retort.

In Spain another method is employed. The sulphuret is reduced in a peculiar furnace without any addition, simply by bringing the flame into contact with the hot ore; the sulphur unites with oxygen and forms sulphurous acid gas, whilst the quicksilver is separated in the metallic state, because, being a noble metal, it has no tendency to become oxydised.

Pure quicksilver is a white, silvery, lustrous fluid, without taste and smell. The metal volatilizes sensibly at all temperatures above 70°, and boils at 670°, at which it may be easily purified from all fixed impurities. At 40° below zero, it is malleable, great contraction taking place in the act of solidification. At common temperatures it is quite unchangeable in air; but if adulterated with tin or lead, loses not only much of its fluidity, but also tarnishes easily. On account of its mobile, restless character, the name of the heathen god *Mercury* was given to it; and, even now-a-days, the term mercurial, applied to an individual, has not lost its meaning.

Alloys of mercury, with other metals, are termed *amalgams*. The property of forming such amalgams with gold and silver, I have already noticed. Next to its medicinal properties, quicksilver is most important for silvering looking-glasses; this is accomplished by an amalgam of tin. The process is briefly this:—" A perfect sheet of tinfoil, somewhat larger than the plate-glass, is placed upon an even table of slate or stone: quicksilver is then poured upon it, and rubbed upon its surface by a hare's foot, or a ball of flannel or cotton, so as to form a clean and bright amalgam. Upon this excess of mercury is poured till the metal has a tendency to run off; the plate of glass, previously made quite clean, is then brought horizontally towards the table, and its edge so adjusted, as by gradually and steadily sliding it forward, to displace some of the excess of mercury, and float the plate, as it were, over the amalgam, the dross upon its surface being pushed on by the edge of the glass, so that the mercury appears beneath it with a perfectly uniform, clean, and brilliant reflecting surface. A number of square weights, of 10 or 12 lbs. each, are now placed side by side upon the surface of the plate, so as entirely to cover it, and press it down upon the amalgamated surface of the tin: in this way the excess of mercury is partly squeezed out, and the amalgam is made to adhere firmly to the glass. The mercury, as it runs off, is received into a channel on the side

of the table, which is slightly inclined to facilitate the draining, and in about forty-eight hours the weights are taken off, and the plate is carefully lifted from the table and set nearly upright, by which the adhering mercury gradually drains off, and the solid crystalline amalgam remains perfectly and uniformly adhering to the glass." (Brande.)

Amalgams of silver, and of another metal, cadmium, are used for stopping decayed teeth.

Calomel and *corrosive sublimate* are salts of quicksilver. The latter is a fearful poison, for which white of egg is the best antidote.

4. ZINC. Latin, ZINCUM. Symb. Zn. Specific gravity about 7·.

This metal is tolerably abundant, and very useful. It is so very slowly acted upon by the air, that it is now most frequently employed for coating iron for the prevention of rust, and is used for roofing, gutters, chimney-tops, &c. In China and India, zinc has been long known, and utensils of zinc, inlaid with various metals, are not uncommon in those countries. It is found in combination with sulphur, as sulphuret of zinc; or, in the more valuable form of carbonate of zinc or calamine. The latter is preferred for the extraction of the metal. The one is first roasted, to drive off the water and carbonic *acid, and* thus an oxide of zinc is obtained. The *metal is* obtained from the latter, by heating it in

clay pots or crucibles, with small pieces of coke or charcoal. At a full red heat carbonic oxide escapes, and the metal drops through a hole in the bottom of each pot, by an iron tube, into a vessel of water. By simple roasting the sulphur may be driven off from the sulphuret in form of gaseous sulphurous acid.

Zinc, obtained from either of these sources, is a blueish white metal, and at ordinary temperatures rather brittle. Between 250° and 300° it is, however, malleable, and may be rolled or hammered into sheets, which retain their malleability when cold. It melts at 773°, and volatilizes at a red-heat.

In commerce, Zinc is known by the name of Spelter, and its ore, the sulphuret, as Blende or Black-jack. The largest supplies come from Silesia.

5. LEAD. Latin, PLUMBUM. Symb. Pb. Sp. gr. 11·35.

Next to iron, lead is the most abundantly diffused of the household metals. Like zinc, it is but slowly acted upon by the air, and owing to its malleability is especially adapted for covering roofs.

The most important ore of lead is the sulphuret, commonly called *galena*, from which this metal is alone procured. In lustre the ore resembles the pure metal, but it is brittle, and requires a white heat for fusion. It occurs massive, and beautifully *crystallised* in form of dice or cubes. It has been

already spoken of, as often containing silver, and the mode of obtaining the silver from it has been described. The process for obtaining lead from its ore is very simple. The mixed ore having been broken and washed, is roasted in a reverberatory* furnace, the temperature being such as to soften, but not fuse it. By this process much of the sulphuret becomes oxydised, and converted into sulphate of lead; much, however, remains unaltered. Now, it is known to chemists that when sulphate and sulphuret of lead are heated together, they re-act upon one another, and produce sulphurous acid gas and metallic lead. The contents of the furnace are therefore thoroughly raked together, and the temperature increased; the melted lead sinks to the bottom, and is run out into oblong moulds called *pigs*.

The mines of Great Britain furnish upwards of 50,000 tons of smelted lead annually.

Pure lead is a blueish-white metal. It is very soft and, when fresh cut, has much brilliancy. It melts at 612°, and is then, by the action of the air, easily convertible into an oxide. It may be cast, without trouble, into a variety of useful forms.

The surface of lead easily tarnishes, and is easily acted upon by soft water. Although a slow, it is a

* *Reverberatory furnaces* are much used when substances are to be exposed to heat without contact with the fuel. The fire-chamber is separated from the hearth by a low bridge of brickwork, and the flame and heated air is reflected downwards by the arched form of the roof. Great heat is obtainable from such a furnace.

most fearful poison. Its salts have a sweet taste, so that in a dilute state it gives no unpleasant warnings of its presence. Fortunately, most waters contain gypsum, the sulphuric acid of which forms an insoluble salt with the oxide of lead. Thus, spring water may be kept with impunity in cisterns of lead, provided the covers be of wood. Otherwise, the pure water which evaporates and settles in drops upon the lid, is liable to dissolve it.

The alchemists gave this metal the name and symbol of *Saturn* ♄.

Some of the oxides and salts of lead are very important. *Red Oxide of Lead*, *Minium*, or *Red Lead*, is used as paint, as well as in the glass-manufacture. It is a tasteless, insoluble, scarlet powder, and contains more oxygen than common litharge. *White Lead*, which constitutes the basis of most paints, is a *carbonate of lead*. The white lead of commerce is prepared by placing sheets of lead over earthen pots, containing a few ounces of crude vinegar. The pots are kept surrounded by spent tan, and closely covered. After some time, the lead is found to be in great part converted into white lead, the carbonic acid of which has been evolved from the tan. *Chromate of lead* is a beautiful yellow pigment, much used in calico-printing, and in painting coach-panels. *Goulard's Lotion* is a salt of lead.

Type-metal is an alloy of 130 parts of lead, with 8 of a metal called antimony.

6. TIN. Latin, STANNUM. Symbol Sn.
Sp. gr. 7·285.

This metal has been known from the earliest ages. Pliny relates that the Phœnicians traded with Britain and Spain for tin. It still occurs most abundantly in Cornwall; and is found in considerable quantities in Malacca, India, and Germany.

The principal ore of tin is the native oxide; but it likewise, though more rarely, occurs as a sulphuret. The oxide, or tin-stone of Cornwall, is known by the names *mine-tin* and *stream-tin*, according to the source from whence it is obtained. The stone, after being ground to powder, is washed for the purpose of removing as much as possible of the earthy matter. It is then roasted, to remove the sulphur and arsenic, with which it is always contaminated. Mixed with charcoal and a little lime, it is heated in a reverberatory furnace for eight hours; the charcoal combines with the oxygen of the oxide of tin in the form of carbonic acid, while the lime, uniting with the silica and other impurities, forms slag. The impure tin thus obtained, is again returned to the furnace, and carefully heated, so as to melt the tin, which runs off into an iron kettle, while the chief impurities remain unmelted. The tin in the kettle is kept in a state of fusion, and agitated by plunging into it wet charcoal, which causes the impurities to rise to the surface, where they are skimmed off.

Thus refined, the metal is cast into blocks of 3 cwt. each.

The purest kind of tin is sold under the name of *grain-tin* : *block-tin* is less pure.

The pure metal has a white colour, and emits a peculiar crackling noise when twisted. Its taste and odour is disagreeable. It is very malleable, as may be inferred from the fact that tin-foil is less than $\frac{1}{1000}$ of an inch in thickness. It melts at 442°, and may then be easily crystallised. Heated above its melting point, it oxidizes rapidly, and is converted into *putty-powder*, or *tin-putty*, a whitish substance used for polishing. By itself, the oxide is infusible; melted with glass, it forms *white enamel.*

Sulphur unites with tin, and forms a compound possessed of extraordinary golden lustre. *Mosaic gold*, or *musive gold*, is a bi-sulphuret of tin. It is much used, especially by paper manufacturers, under the name of *bronze powder*.

Some of the alloys of tin are important. *Pewter* is usually compounded of 20 parts of tin with one of lead, or another metal, bismuth. *Tin-plate* is another most useful alloy. Iron-plate and kitchen utensils may be coated superficially with tin, and thus preserved from rusting away. The only objection is, that the iron, if anywhere exposed, has an increased liability to oxidize, or rust. This is especially the case with tin-plate; hence the superiority of iron-plate coated with zinc instead of tin.

7. Copper. Latin, Cuprum. Symbol, Cu. Sp. gr. 8·86.

Its name is derived from the island of Cyprus, where this metal was first wrought by the Greeks. The brass of the ancients, of which they made their implements, both of agriculture and of war, was an alloy of tin and copper. The alchemists called copper Venus ♀.

It sometimes, but rarely, occurs in the metallic state. The most important ore of copper is the *copper pyrites*, or *yellow copper ore*. It is found in large quantities in the mines of Cornwall. Chemically it is a compound of one part of sulphuret of copper with two of sulphuret of iron. The process of reduction is carried on most largely in South Wales. There the ore is first roasted, by which the sulphuret of iron is oxidized, while the sulphuret of copper remains unaltered. The roasted ore is then strongly heated with sand, which combines with the oxide of iron, forming a fusible slag, which separates from the heavy sulphuret of copper. By a repetition of this process the iron is got rid of; and then the sulphuret of copper begins to decompose in the reverberatory furnace, losing its sulphur and absorbing oxygen. The temperature of the furnace is then raised, and the oxide of copper reduced to the metallic state by the aid of charcoal. The last part of the process consists in thrusting into the melted metal

a pole of birchwood, the object of which is to reduce a little remaining oxide by the combustible gases thus generated. (Fownes.)

With one single exception, copper is the only metal which has a red colour. It is very lustrous, very malleable and ductile. Like tin, it emits a smell when rubbed with a moist hand. Its melting-point has been fixed between that of silver and gold, and is placed by Daniell at 1996°.

Copper is a most useful metal, and many valuable household utensils are formed from it. Unfortunately it tarnishes, or oxidizes, easily. One of its oxides is possessed of a beautiful red colour, which may be easily prepared artificially. Copper vessels, such as tea-urns, are often coated with this oxide.

All the salts of copper are poisonous. Thus we find that when a copper vessel is exposed to moist air it becomes covered with so-called verdigris. The green crust thus formed is a carbonate of copper. It is prepared as a pigment, under the name of green verditer. *Malachite*, which is found in much beauty in the Uralian mountains of Siberia, and in Australia, and made into ornaments, is a native carbonate of copper. *Sulphate of copper*, or *blue vitriol*, is of a sapphire-blue colour. It is much used in the arts as a source of several blue and green colours; and a solution of it is employed in electrotyping. *Verdigris*, a salt of a green or blue colour, is a combination of acetic acid (vinegar) with oxide of copper.

It is a beautiful pigment, but a fearful poison. Care should be taken to keep vinegar from all copper vessels, which should be kept at all times scrupulously clean.

The alloys of copper are most important: Thus *brass* is an alloy of copper and zinc. The proportions vary, and some contain a little lead and tin. Pins are usually made of brass and coated with tin. *Tomback*, *Pinchbeck*, *Dutch-gold*, and *Similor*, are alloys of brass with copper. *Bell metal* is an alloy of copper and tin; so likewise is *Bronze*. *Speculum metal* contains, in addition to copper and tin, a little arsenic. Whilst on the subject of alloys of copper, may be mentioned the existence of a beautiful metal called NICKEL. It is found in the Hartz mountains, and in some few other localities. It is a white, malleable, and difficultly-fusible metal, strongly magnetic. Its chief use is in the preparation of several beautifully white alloys, some of which are only inferior to silver. *German silver* is an alloy of 100 parts of copper, 60 of zinc, and 40 of nickel. *China silver* or *tutenag*, *Britannia metal* and *Argentine*, of which forks, spoons, tea-pots, &c. are made, are alloys in various proportions of copper, zinc, and nickel. Such spoons and forks should not be allowed to remain in contact with pickles or any acid sauces.

8. IRON, Latin FERRUM. Symbol. Fe. Specific gravity 7·8.

Is the most important of all metals. It has not indeed the beauty of colour, nor the fineness of quality which gold and silver have. But the grand difference between iron and other metals is its hardness, and its capability, by a peculiar process, of being made into steel, which is so hard, that it can cut every substance in nature, with the exception of the diamond. It is universally diffused over the earth, and there is no soil that does not contain more or less of the oxide of this metal. It has been known and employed by man from the earliest ages of his existence: the name and symbol ♂ of Mars, the God of War, was given to it by the alchemists.

Native iron is found in small quantities in the Uralian mines. Those immense masses of metal, known as meteoric, are usually termed native iron. But the source, from whence the quantities for the world's supply are drawn, is not from native iron, but mainly from its oxides, and carbonates.

The magnetic iron ore, or loadstone, is black and lustrous; and sufficiently magnetic to take up a needle. It is abundant in Sweden, at Roslagen, and is manufactured into a kind of bar-iron, from which the best steel is made.

Red-iron-stone or hæmatite abounds in Lancashire, near Ulverstone. From it some of the best *iron-plate* and wire is made.

Clay-iron-stone, so called on account of the large admixture of clay with the oxide of iron, is likewise abundant. But the coal formations of Staffordshire, South Wales, and Scotland, from whence the great supply of British iron is obtained, consist of carbonates. They are not, however, pure carbonates of iron, but are mixed with clay, lime, coal, and magnesia.

The process of the manufacture of the metal is not difficult to understand. The clay-iron-stone is first *roasted* with coal, by which the carbonic acid is removed from the carbonate, and the metal remains in combination with oxygen, as red oxide of iron. It is now ready to be *smelted*. This process is conducted in the so-called blast furnace, a tall building 50 or 60 feet high. Into this blast furnace a mixture of equal weights of roasted ore and coal, with one-fifth of limestone is thrown, and powerfully heated by means of a current of air introduced at the bottom. The carbon of coal enters into combination with the oxygen of the ore, and forms carbonic acid, which escapes in the form of gas. The lime unites with the silica of the ore and with other impurities, and forms a slag, which, being lighter than the metal, swims on the surface. In the course of a day and night the iron is found in metallic shape, and is drawn off by taking out a plug made of clay, inserted at the bottom of the furnace. It is allowed to run into a bed of sand, which is formed into

channels and furrows. Iron *cast* in these channels of sand is called *pig-iron.* Such iron is combined chemically with carbon. Wrought-iron is made from cast-iron by the process of decarbonizing. The removal of a portion of this carbon or the *puddling process*, is effected by introducing the metal into a reverberatory furnace; after being powerfully heated and stirred for a few hours, it is made into balls, which are hammered and drawn between rollers, while still hot, into bars.

Iron is a metal of a blue-white colour, fusible at a white-heat. It is very ductile, but cannot be hammered out into very thin leaves, as it becomes pasty before it melts. It admits of being welded or joined by hammering to other pieces of red-hot metal. When exposed to damp air it rusts, *i. e.* unites with oxygen, and forms red oxide of iron. By contact with lime, potash, or soda, iron may be preserved from corrosion, as also by contact with zinc: hence the advantage of zinced iron.

Steel is prepared by heating iron in contact with charcoal. Bars of Swedish iron are embedded in charcoal-powder contained in a crucible capable of resisting heat, aud exposed for hours to a bright red-heat. The iron takes up about 1½ per cent. of carbon, and becomes harder. The product is called blistered steel, from the appearance of the bars. The texture is improved by welding a number of these bars together, and drawing the whole out

under a light tilt-hammer. The most wonderful property of steel is that of becoming very hard when suddenly cooled. If a piece of steel be heated to redness, and then plunged into cold water, it becomes capable of scratching glass. If re-heated, and allowed to cool slowly, it again becomes as soft as ordinary iron. The articles forged into shape are first hardened in the manner described; they are then *tempered*, or *let down*, by exposure to a proper degree of annealing heat, which is often judged of by the colour of the thin film of oxide which appears on the polished surface. Thus, a temperature of about 430° F., indicated by a faint straw-colour, gives the proper temper for razors; that for scissors, pen-knives, &c., will be comprised between 470° and 490°, and be attended by a full yellow or brown tint. Swords and watch-springs require to be softer and more elastic, and must be heated to 550° or 560°, or until the surface becomes deep blue. Attention to these colours has now become of less importance, as metal baths are often substituted for the open fire in this operation. (Fownes.)

To all the valuable qualities of iron that have been mentioned, must be added its usefulness as a medicine. Many springs derive their name from the iron contained in them. Chalybs is the Latin for steel; hence the derivation of chalybeate. There are very few waters that do not contain

traces of iron, indeed I cannot say that in any of the many waters which I have analyzed I have ever found water without it. A quantity of bi-carbonate of iron, the form in which it is usually contained in waters, not exceeding one-fifth of a grain in a gallon, is sufficient to give it a decided taste. When waters contain much of it, they give positive signs of its presence by leaving a yellowish-red stain of ochre on the soil over which they pass; for not only is carbonate of iron insoluble in water containing no carbonic acid, but its tendency to attract oxygen is so great, that when once it comes in contact with air, it, by its conversion into a higher state of oxydation, entirely loses its solubility. Iron-ochre is, therefore, a higher grade of oxydation than that we meet with in clay-iron-stone, or in solution in chalybeate waters. When iron is exposed to the atmosphere it *rusts*, and becomes covered with the red oxide or ochre.

Some of the salts of iron are of immense importance. *Green vitriol, sulphate of iron* or *copperas*, is prepared commercially on the large scale in the alum manufacture, the sulphate of iron being crystallized out of the sulphate of alumina. The *potash-tartrate of iron*, so much used as a tonic in medicine, is obtained by boiling the red oxide with cream of tartar. *Prussian-blue*, the fine blue colour used for dyeing woollen dresses, is a salt of iron. It is used *by washerwomen*, under the name of blue, to hide

the yellow colour of linen. Even the ordinary writing-ink is a salt of iron. There exists in nut-galls, in oak-bark, in fact in many trees, a substance called *tannin* or *tannic acid*, which possesses the property of precipitating glue from its solutions, as *tanno-gelatine* or *leather*. The *tannate of red oxide of iron*, or *ink*, is prepared by adding tannic acid to a salt of iron, in a manner yet to be described in the experimental chapter.

In fact, iron is of universal occurrence. We meet with it in leaves, fruits, stalks, stems, and flowers; in every mineral; in the flesh and blood of men and animals; even milk and water contain it. And as an agent of civilization it ranks so high, that it may be safely called the most important of all metals.

APPENDIX.

SUGGESTIONS FOR EXPERIMENTS.

CHEMISTRY is a science so dependent on experiment, that it may be averred that a man may spend a life-time in reading about it, without attaining to any satisfactory knowledge. We may read about the changes which the air undergoes in the processes of respiration and combustion—we may hear that a burning candle gives off water and carbonic acid—we may see a blue-bell on the solitary heath become red during a thunder-storm—but how much more do these become facts to our minds, when we can prove these results to be constant and ever recurring under similar circumstances. I need, therefore, offer no apology for suggesting a series of experiments on the subjects treated of in this little volume.

PART I.—EXPERIMENTS REQUIRING NO APPARATUS BEYOND WHAT IS TO BE FOUND IN EVERY HOUSEHOLD.

1. Take a fresh candle and light it. Mark the carbonization or apparent blackening of the wick, the melting of the tallow, its rise into the wick, the

form of the flame, and the division of the wick into the part which consumes away and that which is simply soaked in tallow.

2. Move the candle quickly through the air, and note carefully the results, as regards smell, smoke, &c. Hold a dry plate immediately over the flame,—carbon is deposited;—some distance above it—the plate is not soiled.

3. Try at what distance immediately above the flame it ceases to light or even charr a piece of paper.—Repeat the experiment with a lighted camphine or oil-lamp, and find out why the paper will ignite at a much greater distance from the flame, than in a candle not surrounded by a lamp-glass.

4. Put a handkerchief or cloth round the *bottom* of the lamp-glass, so as to exclude the air from the lighted lamp,—it will be extinguished.—Close it at top instead of at bottom, relight it, and mark the extinguishing of the flame.—Take the lamp-glass, hold it over the lighted candle, and prevent the access of air from below by means of a cloth.—Admit the air below, and close the opening with a card. In all these experiments the light is put out.

5. Take a wax-end rather less than 1 in. in height, or an end of a taper; kindle it, and place it on a plain deal table; cover it up with the chimney-glass, and if any air should come in between the glass and the table (which may be known by the continuance in the burning of the candle) surround it at bottom

with a rag.—Admit air at bottom by slightly lifting the glass, and then kindle the light again. Vary the experiment by closing the glass at top instead of bottom.—Put a card lengthways into the upper part of the lamp-glass, so as to divide the opening, and let it stand upon the table over a lighted taper. It will continue to burn, because a current is produced; fresh air rushes down on one side into the glass upon the flame which it feeds, while the foul air escapes upwards on the other side of the card. And this may be proved by the following experiment. A candle that has been burning until a long wick has been obtained, is blown out. If the red-hot wick be held on one side of the opening formed by the card and the half-circle of the chimney-glass, the vapour will be visibly drawn down: if held on the other side, the vapour will be blown into the outer air.—A candle will not burn more than two or three seconds under a tumbler. Why? Because the oxygen of the air in the tumbler is consumed in the process of combustion, and flame cannot exist in its absence.

6. Hold a wine-glass a little distance above the light; in a moment it will become covered with dew in the inside. Why? Because water is always formed when a candle or lamp burns in air. It is deposited as dew upon the glass, because the latter abstracts so much heat, that the air is no longer able to hold all the water in invisible solution.

And this, a continuation of the experiment will prove; for if you hold the glass till it becomes warm, dew is no longer deposited. The heat communicated to the air by the flame is sufficient to prevent the watery vapour arising from the combustion of the hydrogen of the tallow, oil, or gas, with the oxygen of the air, from becoming visible.

7. Remark the fact that a candle gutters in a draught, or when the wick is too long, and think of the reason. Also that some candles require snuffing. Examine the wire round the wick of one of Palmer's decimal candles.

8. To see the effect of draught, or increase of air, upon fire, use the bellows. Let a newspaper hang down to the first bar of the grate, so as to cover in every visible part of the chimney. Think why the fire burns brighter. When you see much smoke escaping from the hot coals, poke the fire, and ask yourself why the smoke disappears, or rather is no longer formed?

9. Light a thin piece of wood, and mark the effects of admission or exclusion of air. Make up a small heap of firewood in the garden, as I have described at page 60, and study the formation of charcoal.

10. Take a spoonful of brandy, *and after having corked the bottle*, set fire to the spirit contained in the spoon. Mark the feebleness of the light, and *think* over the causes of the brilliancy of flame.

11. Bring an externally dry decanter filled with cold water from the well into a warm room. Breathe on a penknife, and ask yourself in both cases where the water that bedews the decanter and the knife comes from. You *see* your breath in winter, and on cold days in spring—why not on warm summer days? Having proved the presence of water in the air by the decanter experiment, think about dew, and try to increase your knowledge about it. Take a thermometer into the fields of a warm summer's night, when the sun is setting. Mark the lowering of the temperature among the grass, and the consequent fall of dew. Feel the leaves of trees. Pluck off a handful, lay them for half-an-hour on the gravel walk, then quickly heap them round your thermometer, and mark its fall.

12. Your knife rusts in moist air, not in warm dry air. Verdigris, so-called, forms on copper saucepans left in moist air. Why? Think on the processes of oxydation.

13. Take some milk, warm it in a cup, and add a few drops of vinegar. Throw it upon a filter of linen, and regard the curd. Shake some cream in a small medicine bottle until the butter separates.

14. Take some flour, make it into paste with water, and wash it in a fine muslin or linen cloth in a stream of water. Examine the gluten which remains, and the starch which makes the water *milky*.

15. Put an egg, or egg-shells, into a basin, and pour vinegar upon them. Place the basin on the hob, and watch the results. (An eggshell consists of carbonate of lime or chalk. The vinegar will dissolve the lime of the carbonate of lime; carbonic acid will escape with effervescence, and you will obtain a solution of acetate of lime).

16. Put a pinch of whitening into a champagne glass, cover it with vinegar, and plunge a wax-end, fastened to a piece of wire, into the glass. Ask yourself why it is extinguished.

17. Throw a piece of iron into the fire. It will not melt. If you have a ladle, melt some lead in it. Try which melts most easily, a piece of white window-glass or a leaden bullet. Think about the melting-points of various metals, and in making the above experiments, remember it is as satisfactory to melt a small bullet as a piece of the size of a cannon-ball.

18. Dissolve a few grains of hard soap in clean rain-water, and add a few drops of this solution to hard water. You will find the soap curdle. The lime of the water forms, with the fatty acids of the soap, a greasy insoluble lime-soap, while the soda of the hard soap combines with the sulphuric acid with which the lime of the hard water is usually associated. Until, therefore, the lime is thrown *down* from the hard water, the soap will not begin *to act* as a cleansing agent.

There are other experiments which will suggest themselves to the young student, and which I therefore need not enumerate.

PART II.—EXPERIMENTS REQUIRING THE EXPENDITURE OF BUT FEW SHILLINGS.

1. To show the carbon in various household substances. Char pieces of bread, meat, sugar, wood, cloth, paper, or quill-pen. In all of them the presence of charcoal may be proved. Sudden heat causes the hydrogen and oxygen of a compound to unite, because the affinity of these two elements is greater for each other than for carbon; the consequence is, that charcoal is always separated first, when a compound containing hydrogen and oxygen, in addition to carbon, is strongly heated. But this separation of carbon may be shown in a more striking manner. Take two or three lumps of white sugar, place them in a small cup, moisten them with a few drops of boiling water, and add an eighth of an ounce of oil of vitriol. The lumps will be seen to change colour. Great heat is evolved, the lumps swell up to more than four times their size, and present all the appearance of porous charcoal. (Care must be taken not to handle the charcoal, until the oil of vitriol has been removed by repeated washings with cold water). Tea, coffee, cheese, starch, arrowroot, sago, tapioca, white of egg, in fact, every thing that is eatable, may be proved to contain carbon.

The sooner, therefore, the young student loses the idea that a substance must be black which contains carbon, the better.

2. To prove that the air is a compound of gases, purchase a gas-jar for a shilling, an apparatus like a stoppered bottle without a bottom, and capable of holding about a pint, a small porcelain cup for 2d., and a common clay pipe, with rather a long stem, half an ounce of spirits of wine, and bottle, for 4d., a two-ounce funnel 4d., and a sheet of white filtering-paper for 1d. If you put a few drops of spirits of wine into the cup, float it upon a basin of water, and if, after setting light to the alcohol, you immediately invert on it a tumbler or the gas-jar, so that the rim touch the water on all sides, you will obtain the same results, however often you may repeat the experiment. The spirits will burn but a few seconds, dew will fill the inside of the glass, the result partly of combustion, partly of simple evaporation, and the water will rise in the glass to a higher level than that in the basin, corresponding to one-fifth of the contents of the glass; the gas, then, that alone supports combustion forms one-fifth of the bulk of the air, for if the student examine the gas that remains in the gas-jar, he will find it will not support flame. A lighted taper, suspended by a piece of thin copper wire, plunged, by removal of the stopper, *into the* gas-jar, is immediately extinguished. Lime-*water* will prove the presence of yet another gas;

for if a tumbler be half-filled with it, and poured from some height backwards and forwards into another tumbler, the clear liquid will become clouded by a white precipitate. Oxygen alone supports combustion, carbonic acid precipitates lime-water, and nitrogen extinguishes flame.

3. To prove that the air changes its character by respiration, as well as by combustion, fill the gas-jar with water, by simply withdrawing the stopper, and plunging it into a slop-basin filled with water; when full, stopper it, and hold it so that the rim at the bottom is kept under water; now breathe the air from your lungs through the tobacco-pipe into the jar, the gas by its lightness will rise up through and displace the water; and when full, transfer the jar carefully to a cheese-plate, by immersing the plate under water, and closing the bottom of the jar with it before you place it upon the table. This part of the experiment you must perform carefully, for, if you admit air, it will fail. On immersing a lighted taper into the jar it will be extinguished. If the experiment be performed with care, the result will be constant. The oxygen of the air is removed by the blood, and in its place carbonic acid is substituted; this, too, may be easily proved. Fill the gas-jar out of doors with ordinary air, put about half-an-ounce of lime-water into a cheese-plate, place the jar upon it, and shake the enclosed air with the lime-water; because the amount of carbonic

acid in the air is comparatively very small, only a slight turbidity of the lime-water will be perceived; but if you test the air breathed out of your lungs in a similar manner, pouring in a little lime-water, instead of using a lighted taper, the lime will, by agitation, be precipitated in white flakes. It has been stated, in this book, that the use of the blow-pipe is to increase the heat of the flame; and here I would recommend the student to practise a most instructive experiment. The air employed for the blow-pipe is simply external air taken into the *mouth*, and propelled by the cheek muscles. And the difference may be strikingly exemplified, by examining the air emitted from the lungs, and that propelled simply by the mouth muscles. The air from the first extinguishes light, and strongly precipitates lime-water; in the latter the taper burns as well as in pure air, and lime-water is only slightly precipitated. If a taper be burnt within the gas-jar, and fresh air be excluded from below by placing it upon a plate filled with water, it will be extinguished as soon as the oxygen of the air is consumed. A part of it will be found to have assumed the form of water, another of carbonic acid, by uniting respectively with the hydrogen and oxygen of the candle. The water may be seen, the carbonic acid detected by lime-water. Combustion and re*spiration* are therefore very similar in their results.

4. *To* prove that pure carbonic acid does extin-

guish light, and precipitate lime. A small Woulfe's bottle, with gas-delivery-tube and safety-funnel, may be purchased for two shillings, and will be found very useful. Take a quarter of an ounce or more of broken white marble, put it into the bottle, pour a little water over it, replace the safety-funnel, and, having seen that its straight tube just dips under water, pour half-an-ounce of spirits of salt or hydrochloric acid down it. Effervescence arises from the escape of carbonic acid, which begins immediately to pour out of the delivery-tube. If the latter be dipped into a wine-glass full of lime-water, the whole of the lime is quickly precipitated as white carbonate of lime, which will be redissolved, if the flow of the gas into the lime-water be continued. If the gas-jar be filled with this gas, by displacement of the water, its properties will be found to be a power of extinguishing flame and of precipitating lime-water. As the gas is poisonous, care should be taken not to inhale it freely. Another instructive experiment is the weight of the gas. If the delivery-tube of the carbonic acid apparatus dip into an empty wine-glass, or, to speak correctly, one filled with air, the carbonic acid will displace the air and fill the glass. If a lighted taper be placed in another wine-glass, the carbonic acid may be poured out upon it, and although it is invisible, its effects will be noticed by extinguishing the taper in the other glass.

5. To prove that germination is not dissimilar to respiration and combustion. Take some mustard-seed, moisten them with a little water upon a cheese plate, and place the stoppered gas-jar upon it, so as to enclose them. In three or four days they will have sprouted, and, on examination of the air, it will be found to extinguish a lighted taper and strongly to precipitate lime-water. And not only in this respect does germination resemble respiration and combustion, but in another also. It ceases in absence of oxygen. For seeds will not sprout at all in an artificial atmosphere of carbonic acid gas or of nitrogen. Oxygen is therefore essential to it.

6. To prove that decay likewise alters the air. If dying leaves be placed under a bell-glass, or the gas-jar, so that fresh air has no access, decay will not only cease as soon as the oxygen is consumed, but a lighted taper will be extinguished.

7. To prove that liquid water and ice only differ as regards latent heat. Take any quantity of snow at the freezing point, or 32°, and mix it with an equal weight of water at 172°, the snow instantly melts, and the temperature of the mixture is still only at 32°; here the water is cooled 140°, so that 140° of heat have disappeared altogether. Steam can only be considered as water combined with a greater amount of caloric ; for, however long we *boil water* in an open vessel, we cannot make it in *the smallest* degree hotter than its boiling point.

Prove this. Water, in being converted into steam, combines with more than five times the amount of caloric necessary to boil ice-cold water, and occupies a space 1,800 times greater.

8. To prove that all evaporation produces cold, owing to the fact just stated, that liquids require much heat to convert them into vapour. Pour some ether upon your hand, drop by drop, the sensation of cold will ultimately become painful. Repeated sprinkling of ether over the person would be as surely productive of death as freezing, for the evaporation of the ether would quickly carry off the life-heat of the body. Water thrown upon a fire acts in the same way; it becomes vaporized at the expense of the greater portion of heat it contains.

9. To prove that when liquids become solid, heat is evolved. Take a lump of quick-lime, and pour over it one-fourth of its weight of water, the latter will be absorbed, and yet the lime remain dry. At the same time such intense heat is evolved that it has been applied with success for culinary purposes. The water in this case becomes solid, and the heat evolved in lime-slaking proceeds chiefly from the solidifying water.

10. To prove that flame requires a high temperature for its existence. A cold substance placed in the flame of a candle causes a deposit of soot. Bring a mass of iron close to a flame, it will be extinguished on account of the conducting power of

the metal. Depress a piece of wire-gauze upon a gas-jet, you will find the flame will be cut off just where it touches the gauze; the inflammable matter of the flame passes through, but, in its passage through the gauze, is so far cooled as to be extinguished. Bring a piece of lighted paper to the upper side of the gauze, and the gas will be rekindled. Vary the experiment. Place a piece of camphor, of the size of a pea, (and you may buy sufficient camphor with a penny for fifty such experiments,) upon the gauze, which may cost threepence, and heat it below; it will burn below with a bright white flame, yet, so great is the cooling power of the gauze, that, notwithstanding the volatile nature of camphor, it does not take fire on the spot where it lies. Remark how often the gases which ascend from a dull fire, and are rendered visible by slight admixture with smoke, become enkindled, when a well-directed thrust with the poker introduces them into more immediate contact with heated embers, and with air.

PART III.—EXPERIMENTS EASY OF PERFORMANCE, BUT ATTENDED WITH MORE DANGER AND EXPENSE.

1. To study the character of oxygen unmixed with other gases. Take 100 grains of chlorate *of potassa,* and mix carefully with 30 grains or *thereabouts* of black oxide of manganese. Put the

mixture into a clean Florence flask, the mouth of which is connected by means of a cork with a gas delivery tube, and apply gentle heat. As it is convenient to fill several bottles before experimenting, it is advisable either to buy a pneumatic trough, or to make some simple arrangement with a piece of tin-plate, so cut, that it will stand like a little table in the basin. This apparatus must be just covered with water, and, provided the basin is deep enough to fill the gas-jars, the production of oxygen may be proceeded with. Place the tube so that the gas may be collected in the jars and fill them, taking the precaution to reject the first flow of gas, being mixed with the air contained in the flask and the tube. 100 grains of the chlorate yield 40 grains of oxygen, or about 3 imperial pints; it parts in fact with the whole of its oxygen, and is changed into chloride of potassium. Introduce a glowing taper into the gas, it instantly bursts into flame, and burns with far greater brilliancy than in common air; the oxygen is consumed by combining with the carbon and hydrogen of the wax. Into another jar introduce a small piece of ignited charcoal, attached to a piece of copper wire; it bursts into flame, and burns with bright scintillations; carbonic acid is formed, the presence of which may be detected by agitation with lime water. Into another jar introduce a piece of phosphorus, of the size of a pea, which may

be most conveniently placed in a deflagrating spoon; ignite it *in the gas* by means of a red-hot wire; it burns with inconceivable brightness, and affords a good illustration of the necessity of a heated solid substance for the production of a bright light. The snow-like substance which forms is phosphoric acid, which, however, is so soluble in water, that it soon disappears from the walls of the jars. The acid produced is very sour, and strongly reddens litmus. Repeat the experiment in another jar with a small coil of watchspring, split up at the end, and tipped with melted sulphur; ignite the sulphur, and as the steel becomes red-hot it combines with the oxygen, forming black oxide, fused balls of which, in a state of white heat, drop to the bottom, and melt into the plate upon which the jar is placed.

2. To study the character of hydrogen. Boil some water in a kettle for a quarter of an hour, so as to expel all air: let it cool, and then carefully fill a test-tube and a small basin with the water, press a piece of sodium, of the size of a pea, on to a piece of wire, and introduce it *quickly* into the tube, just under water; the metal leaves the wire, rises up in the tube, and decomposes the water; its oxygen unites with the sodium to soda, which dissolves, while its hydrogen is set free with effervescence. The tube is filled with a colourless gas, *which burns with a pale blue flame on the application of a light,* water being the result of the com-

bustion. Put half-an-ounce of granulated zinc into a Woulfe's bottle, supplied with safety-funnel and gas-delivery tube, cover it with four ounces of water, and add by degrees, about three quarters of an ounce of oil of vitriol. Effervescence ensues, which is much increased by the heat produced by the union of the sulphuric acid with the water, and the hydrogen may be collected in the same manner as other gases which are insoluble in water. One precaution is *very needful*, never to collect the gas until the air in the Woulfe's bottle has been entirely expelled. It is, therefore, the safest plan to reject the first pint of gas which passes over. A lighted taper introduced into the gas is extinguished, but the hydrogen itself, in contact with air, burns with flame. Observe, too, the deposit of dew in the jar after combustion, which is the water formed by the combination of the hydrogen with oxygen. Mark its lightness, you will find it impossible to preserve it in an open jar for upwards of a few seconds: it is used for filling small balloons. Fill a soda-water bottle with water, and displace it with two-thirds hydrogen and one-third oxygen, and apply a light: the gases unite with explosion, and water is formed. (It is to prevent danger that I have advised caution: strong bottles with narrow apertures have been fractured by the approach of a light, and much mischief resulted. The experiment, however, may be safely performed as just described).

3. To study the nature of ammoniacal gas, a chemical compound of nitrogen and hydrogen. As water is capable of absorbing 680 volumes of this gas, it is impossible to collect it over water. But many of its properties may be best studied in the solutions of the gas, sold in the shops as caustic ammonia. It is possessed of a most pungent taste and smell, and, under various forms, is much used by ladies, as smelling salts, sal-volatile, &c. It blues reddened litmus-paper, and turns turmeric-paper brown. The gas is much lighter than air, and may be easily obtained by boiling the ammoniacal liquid. For this purpose a Florence flask is best employed, into which pour half-an-ounce of strong caustic ammonia. Instead of employing a gas-delivery tube, place a straight tube in the perforated cork, and apply heat. Wide-mouthed bottles must be used to collect the gas; these are held so as to admit the tube, the gas rises and displaces the air so quickly, that several pint bottles may be filled in a minute. When three or four bottles have been filled, experiment as follows:—Remove the stopper from one of the bottles, close the mouth with a piece of glass, and invert it under water; the most rapid absorption takes place, and the bottle becomes filled with a very dilute solution of ammonia. In another bottle the flame of a lighted taper is extinguished, and the gas itself burns momentarily with a pale green flame.

4. The properties of potassium, the basis of potash, are sufficiently striking, and may be easily studied. A small piece, of a grain weight, will suffice. It may be cut with a penknife, and then exhibits a silver-white surface, which immediately tarnishes by attracting the oxygen of the air. Its affinity for oxygen is so great, that it must be kept under Persian naphtha, a compound of carbon and hydrogen. A small piece of the metal thrown into a few drops of water in a saucer, bursts into flame, is carried rapidly about, and is quickly dissolved. The water is decomposed ; its oxygen unites with the potassium and dissolves, whilst its hydrogen is inflamed by the heat of the combustion, and burns with a violet flame, from admixture with a little volatilized potash. The remaining water will be found on examination to possess a caustic (burning) taste, and to blue reddened litmus paper. On evaporation caustic potash is left, a white substance, which, by attracting moisture from the air, deliquesces and forms a liquid. Caustic potash is a combination of potassium, oxygen, and water. Its affinity for carbonic acid is as great as that of the metal for oxygen, or of the oxide for water. On exposure to the air for a few hours, it will be found to effervesce on the addition of a few drops of vinegar, a property not possessed by the oxide. Carbonate of potash may be prepared from a stick of wood, by burning it and dissolving the white or

grey ash in a little water. The filtered solution will be found to effervesce with acids, to possess a caustic taste, and to blue reddened litmus. On evaporation, a white carbonate remains, which quickly attracts water and deliquesces. From the carbonate of potash of the shops, caustic potash is prepared, as described at page 127. Potash and its salts are most useful. Glass and soft soap contain it. If sand be boiled for some hours with strong caustic potash, some of it is dissolved, and a silicate of potash is obtained. For fats it has the very strongest affinity. A piece of rag soaked in oil is completely freed from it by boiling in potash, as the student may discover by experiment.

5. The properties of sodium and of soda are not very dissimilar from those of potassium and potash, yet are the differences sufficiently striking. Sodium is a whiter metal, and does not burn on cold water, although the action is nearly as vehement, and the solution of the soda as rapid. Soda communicates a yellow colour to flame, as may be seen by throwing a grain of the metal into boiling water. The salts of soda effloresce, by giving off water of crystallization.

6. Lime is the oxide of calcium. It may be prepared by heating a chip of marble in a bright fire. It is white, and easily pulverized. It is caustic, and destroys the paper or linen in which a piece may be wrapped by way of experiment. A few drops of water poured upon quicklime are imme-

diately absorbed ; abundant heat results, and a fine powder, slaked lime, is produced. Hydrate of lime, or slaked lime, dissolves sparingly in water, and the lime-water thus formed quickly attracts carbonic acid. It must therefore be kept in well-stoppered bottles, and is useful for the detection of carbonic acid, with which it forms a white powder, carbonate of lime or chalk.

7. Alumina, or the base of clay, may be easily obtained from alum. It falls from a solution of alum, on addition of ammonia, in form of a thick colourless jelly. It is thrown upon a filter, and washed well with water. When dry, it is a white powder, insoluble in water, and therefore perfectly tasteless. It adheres to the tongue, and is soluble in acids and alkalies. When heated to redness, it loses its water of combination, and becomes converted into alumina. It is then insoluble in acids and alkalies. Next to silex, alumina is the chief constituent of soils.

8. Iron-rust, or the red oxide of iron, contains the same quantity of oxygen as alumina, which in many respects it resembles. On the addition of ammonia to the perchloride of iron, the red oxide precipitates in the form of a brownish-red flocky jelly. By dissolving iron in warm nitric acid, its properties may be further studied. Carbonate of soda throws it down from its salts as hydrated peroxide of iron ; during the operation, the carbonic

acid escapes with effervescence, as it does not enter into combination. When heated to redness, the hydrate loses its water, and the red oxide resulting is only slightly soluble in acids. Peroxide of iron is very abundant. It is contained in flesh and blood, in vegetables and in bread. Dissolve the ash from a piece of burnt meat in spirits of salt, (hydrochloric acid) filter and add ammonia; hydrate of the red oxide will be precipitated. Yellow prussiate of potash detects minute traces, by exhibiting a beautiful blue colour, when added to the solution containing iron. Tannin, or the yellow mass found in gall-apples, is likewise a good test. Ink is a pertannate of iron, and may be prepared by adding tannin to a persalt of iron. A black ink may be made by boiling two and a half ounces powdered nut-galls in thirty ounces of water, for a quarter of an hour. Filter and dissolve in it, in an *open* vessel, one ounce of gum and one ounce of green vitriol (proto-sulphate of iron). When it is dark blue, it may be bottled for use. Green vitriol is a proto-sulphate of iron, as stated at p. 155. The attraction of prot-oxide of iron for more oxygen is so great, that it is impossible to preserve it pure. On addition of ammonia to a solution of proto-sulphate, the originally white precipitate immediately becomes green, and passes through every *possible* shade, till it becomes at last converted into the hydrated red oxide of iron. The metal iron

dissolves with ease in weak sulphuric, nitric, and hydrochloric acids. Hydrogen is given off when sulphuric or hydrochloric acids are employed. A piece of steel may be easily distinguished from one of iron; for, if a drop of nitric acid be let fall upon it, it will occasion a black spot, but will have no such effect upon wrought iron. Even so, when steel is dissolved in nitric acid, charcoal will indicate itself by its characteristic black colour. An iron wire only one-tenth of an inch in diameter will carry 150lbs. without breaking.

9. The presence of copper in an ore may be easily discovered. Boil a piece with a little nitric acid, dilute with water and filter. If a nail be now placed in the filtered solution, which, if copper be present, will probably be of a blue colour, the copper will be precipitated upon it in its natural colour. Copper-wire of one-tenth of an inch in diameter will support a weight of 300lbs. Expose a piece of copper, moistened with vinegar, to the air, it will soon be covered with verdigris. The ordinary oxide of copper is that which is obtained by dissolving the metal in acids. Ammonia throws down the hydrated oxide of copper from its solution in form of a bluish-white precipitate, which redissolves when excess of ammonia is added, giving rise to a deep purple liquid. Yellow prussiate of potash is an excellent test of the presence of copper, with which it forms a red-brown precipitate.

10. Lead dissolves easily in nitric acid, and forms a beautiful white salt. From the nitrate thus resulting, or from a solution of sugar of lead, (acetate of lead) the properties of prot-oxide of lead may be conveniently studied. Spirits of salt throws down white chloride of lead from such solutions. Sulphuric acid precipitates insoluble white sulphate of lead. Ammonia, potash, and soda, throw down white oxide of lead. When lead is melted in an iron ladle, a scum is soon formed, which is the ordinary prot-oxide of lead. By continuing the heating of the yellow oxide in a reverberatory furnace, it can be made to take up more oxygen, and become changed into red oxide of lead. Of this, take one quarter of an ounce and mix it with a few grains of charcoal; fill the bowl of a tobacco-pipe with it, place this in the middle of a common fire, and soon the lead may be poured out in the metallic form. In this process the carbon combines with the oxygen of the red-lead to carbonic oxide, and the lead is reduced.

11. The metal zinc has more powerful affinities than lead, so that if a piece of zinc be suspended in a solution of sugar of lead, a solution of acetate of zinc is obtained, whilst the lead is thrown down in form of a lead tree. Indeed, zinc has so great an affinity for oxygen, and its salts are so permanent, that none of the ordinary metals will precipitate it from its solutions in the metallic form. Ammonia

throws down the hydrated oxide of zinc of a white colour from its solutions; excess of ammonia re-dissolves it. Zinc, if beaten out in thin leaves, will take fire from the flame of a candle. In the fire, the combustion of zinc is most beautiful. Zinc dissolves in weak sulphuric acid with effervescence; sulphate of zinc is formed, and hydrogen is set free.

12. Tin is one of the lightest of the metals, and so soft and ductile, that it may be beaten out into leaves thinner than paper. It emits smell when rubbed. If tin be heated in strong nitric acid, the whole of the metal will be converted into a white powder, which is a hydrate of the peroxide; but if this be heated so as to drive off the water, it assumes a yellow colour, and is then the peroxide of tin.

Further experiments might be suggested, but if these give a taste for chemistry, other books will be searched with advantage by the young student.

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THE END.